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Photo by International Film Service, Inc.

A large portable searchlight that can be elevated and turned to throw its beam in any direction

MILITARY SEARCHLIGHTS [See page 148]

Co-ordination in Munition Work*

A Study of Output Under British Conditions

One of the greatest anxieties confronting those who have the control of munition factories is the co-ordination of the production of the separate details. There are some scores of separate pieces in any complete shell, the number varying with the type and size. Now if any single component, however small and trivial, is lacking, the shell cannot be built up and completed. The absence of any single pin or screw or needle, or the failure of any single piece to pass the limits of inaccuracy, will dislocate the work of assembling.

Taking another aspect of this subject: the shell is built up of completed elements, such as the steel case, the brass cartridge case, the fuse, the primer, the bullets, the powder pockets, and the tubes. Each element, to be fitted as a complete entity to its fellow portions of the shell, must be completed in big batches of separate units in equal numbers, or the shells cannot be assembled. Yet all these are seldom made in one establishment, but usually in several distinct shops, which may be situated hundreds of miles apart. Difficulties and delays due to these conditions have occurred with serious results. Such hindrances cannot be totally eliminated, but they can be minimized by the exercise of a cautious technical control and a system of minute clerical records.

TIMING

It may be well to state that results are but slightly influenced by what is understood as hard work, or in the shops as "driving," which relates to manual labor. It is all done—assembling excepted—by machine-tools, the output of which is almost entirely under the control of the shop managers and of the tool setters; that is, the time which is occupied by any operation is mainly, though not quite wholly in every case, taken out of the control of the individual who has charge of the machine in which it is being done. It can vary only slightly from a standardized time, because the actual operation is automatically performed by the tools which are appointed and rigged up for the purpose by the tool setters, and the speeds of which are stated. When tasks are being regularly performed under these conditions any departure from scheduled times, if it amounts only to two or three minutes, or in some minor operations to seconds, would be observed, the explanation sought, and the cause dealt with. While it is true that the time for every operation is standardized, opportunities for variations occur in the times of changing of pieces—the taking out of a finished article and putting a rough one in its place. But even the times necessary for these are known very closely when route systems are observed, and on highly repetitive tasks deliquents are called to account. Moreover, piece prices act as an incentive to efficiency. Hence the first essential condition to co-ordination is a very close, if not an exact, timing of every operation.

ORGANIZATION ESSENTIAL

Before any work is begun in the machine shop its organization has to be planned by the management in consultation with the expert heads of departments. Though official pressure for early delivery is insistent, the capabilities of the firm's plant have to be minutely considered if inefficiency is to be avoided. The successive stages in manufacture must be discussed and balanced and synchronized, and conceivable alternatives, when such are practicable thought out. The more extensive the character of the product that is undertaken the greater is the caution called for, and the more deliberate the preliminary investigations should be. To produce the whole of the work on a shell, including the complete fuse, involves much more planning and organization than does the manufacture of a single element only, such as the case, or some portion of a fuse. Yet even one piece offers alternatives, and a large aggregate product of a single article involves a considerable outlay on machine tools, jigs, and fixtures.

TECHNICAL SKILL

Behind the determination of fixed times for tooling there is a vast amount of technical skill and long experience gathered in work which is generally unrelated to that of shellmaking, but the underlying principles and the great elements of practice are of the nature of axioms. Even so several tentative designs of tool arrangements may have to be set up and timed before the one which recommends itself as the best possible of all is evolved. This preliminary work involves a great deal of detail, and includes the forms of the cutting tools to be used and the speeds and feeds. Design is influenced by the class of machine employed, by the nature of the assistance which is rendered to the work of the machine in the form of fixtures, jigs, or other appliances, by the chucks in lathes, and by the limits of measurement that are imposed. These details become complicated when operations are multiplied and combined in sequence on a single machine. Then the elaboration involved increases the cost, and often, too, makes greater demands on the skill or the attention of the individual who is in charge. But this also may be justifiable or necessary, since the object sought is to get the best ultimate results from the machine shop.

CAPABILITIES OF PLANT

To co-ordinate output an exact statement of the capabilities of the machines and tools that constitute the firm's plant must be put on record. Only in small shops can these be carried in the memory. The capacities of every machine, its range of speeds and feeds, must be available for reference for those who have the task of working out an accurate scheme of production. Though the general aim should be to operate each machine at its full capacity, yet that may not always be possible, as happens when the relative columе of work is not sufficient to secure maximum output. In this preliminary scheming, moreover, no rigid, no unalterable arrangements can be adopted, since in the light of later experience modifications may be effected with advantage, both to reduce costs and to synchronize the times for making up aggregate sets. The operators also are factors which vary. Those who have acquired facility in the exercise of their duties may have to be removed, and others less skilful be substituted, with lessening of output, which again may entail the making of some rearrangements to maintain the aggregate times. In the rigid interdepedence of machine operations, no one machine stands alone from the point of view of co-ordination of results. Each is a unit in the great schemes and very often an insignificant one; yet it is as vital and essential as a screw or a pin is in a big mechanism. The related units may be situated either adjacent or in another department, but their position does not affect their relationships. Their several outputs have to be strictly co-ordinated if the smooth progress of the total output is not to become dislocated.

EXTENSIONS OF PLANT

Firms whose financial position enables them to purchase new plant are more favorably situated for the production of munitions than those who are not so placed. It is true that almost any machines can be used, or adapted, to deal with certain sections of munition work. But small firms who are limited to the use of an existing plant are correspondingly handicapped. When new machines are being purchased it is not judicious to select those which are strictly specialized for the performance of the sections of work which alone they are designed to accomplish unless the volume of the contract undertaken is sufficient to recoup the outlay, or unless the machine is suitable or readily adaptable to the firm's ordinary manufactures, to be resumed in normal times. If the volume of work accepted is very large, the outlay on the highly specialized machines may be wholly justified, even though they may be scrapped subsequently. But if that is not the case, those machines should be selected which are of general utility, and therefore suitable for general service and permanent retention.

The more highly specialized the character of the product that is undertaken by a firm, the more minute and careful must be the study given to the arrangements of the machines and their services. The usual location of machines of a kind in close association is often properly abandoned for that which is qualified better to deal with production of the specialized unit—the one piece that is manufactured in enormous quantities. The machines are then arranged not by their types, but strictly according to the sequence of their operations. Lathes, drills, milling machines, and others may thus be grouped together. The advantage over the usual system is unquestionable, but it is essential to success that the product be highly standardized, and its volume be almost unlimited.

STANDARDISATION

The manufacture of shell parts has been a marvellous object-lesson, and a training to many firms, in the standardization of parts, which has had no parallel in any other assembled mechanisms ever produced. Hundreds—probably some thousands—of firms have been compelled to adopt the methods associated with standardization and interchangeability, who had previously got along very well without them when dealing with their old pre-war products manufactured in relatively small quantities. But shells of a single type and size are exactly alike, and are made in batches of hundreds of thousands. These have no parallel in aeroplane parts, or machine tools, or motors that are built by different firms. If these, though turned out by different firms, could be standardized, vast economies would result without sacrifice of efficiency. The entrance into munition work of thousands of firms who had never attempted anything like it before has been a valuable training in gauging and tool making to secure interchangeability, of which they had no previous experience. The heavy cost of gauges and tools—apparently prohibitive when regarded out of true prespective—has been demonstrated to be an excellent investment. This is a lesson which will be retained when normal conditions of manufacture are resumed.

CLERICAL WORK

A considerable amount of clerical work is essential if an accurate record of production is to be kept. Without this it would not be possible for foremen and managers to grasp the entire scheme of co-ordinated output in a single big shop, much less in shops that are situated far apart, and associated for unit production. But the work can be followed daily by the help of a chart, having the name or number of each component entered on it, and the numbers that are required to complete sets. By recording on this the daily and weekly output of each component, it can be see at a glance whether some are lagging and others exceeding the numbers wanted. These charts vary in their details.

MEASUREMENT

The matter of correct measurement is one of high importance which must not be neglected. Every dimension on every piece from the largest to the most minute is measured and inspected with a fixed gauge. The limits fixed vary in different pieces, ranging from 1/500 in. in the coarsest to 1/2,000 in. in the finest. The total weight of a shell is also limited. The separate measurements on the parts of a complete shell number hundreds, and all have to be tested while the work is proceeding in the shops, and afterwards by the inspectors appointed by the Government.

MACHINE OPERATIONS

The principal machine-tool operations on shell parts are reducible to a few typical kinds. They include chiefly turning, boring, drilling, and threading. It is because these are few and elementary in character that existing machine tools which are found in all shops, though occurring in different guises and in varying relative numbers, are readily adaptable to the work. Practice is not restricted to the employment of one kind of tool for the production of a given result. Alternative methods with similar results can be secured in several diverse machines. Hence the choice is narrowed down to the relative economies offered either in time or in the question of trained or of unskilled labor.

APPORTIONMENT OF TASKS

When the details of the work done on, say, a shell case are subdivided between common lathes, or turret lathes, or drilling machines, it must be obvious that the times occupied in the different operations will not be alike. Some will take twice or three times as long to accomplish as others. Unless this fact is countered by co-ordinated arrangements, some sections of the work will get far ahead of others, and the result must be that some machines will presently be lying idle, with congestion of the work and disorganization of the arrangements. Here the influence of far-seeing management and of daily records comes in. The times of each separate operation having been first ascertained on a standard basis, the shortest single operation is selected, and those which require longer periods are brought into harmonious relation with the basis time by pressing additional machines into the service. Thus if one operation occupies 10 minutes and another half an hour, three similar machines, if they can be obtained, will be apportioned to the latter, and the longer operations will be completed within the basis time. Manufacturers lay themselves out to produce batteries of machine tools, some similar but others dissimilar, in order to carry the product through from the start to finish on the time basis necessary to terminate the whole of the operations simultaneously.

*Engineering Supplement of the *London Times*.

MODIFIED MACHINES

Many ingenious modifications are made in standard machines of general utility which are arranged in groups or batteries for working on basis times. Turrets are fitted to the carriages of common lathes. Chucks are designed to hold one size of shell with an instantaneous grip, and expanding arbors also. Fixtures receive parts that have to be drilled. Every machine may have one or more of these helps. Some will have aids to facilitate handling heavy shell cases. Sometimes half-a-dozen lathes may be occupied in performing identical tasks on pieces of work only once chucked. In others a piece may be chucked in lathes in succession, each performing some separate duty, simple enough but dissimilar from that done in each of the others—so minutely is manufacture now cut up in its details the better to utilize all machines, to facilitate the progress of the work, and to utilize girl labor. Thus also more than one machine may often be placed in charge of one attendant.

SUB-LETTING

In the co-ordination of production the sub-letting of portions of munitions has assisted very materially in increasing the output. In a relatively slight degree this practice was adopted in pre-war times; but it was rather discountenanced by firms of repute, who preferred, when possible, to manufacture all details in their own works, rather than be hampered by responsibilities for other firms. But the present system of rigid inspection both for tests of materials and for machining limits have nearly nullified these apprehensions. The case stands thus:—

In all munition work, taken in its most comprehensive meaning—in shells, engines, aeroplane parts, etc.—there are numerous items which are of an extremely plain character, so very plain indeed that they involve only a bit of the simplest turning, or boring, or shaping, or grinding, so simple that the smallest shops are competent to deal with them, and girls or boys may be put in charge under skilled supervision. True, the limits are always set finely, and the results are gauged. But the chief responsibility is thrown on the tool setter, following the suitability or the accuracy of the machines themselves. There are hundreds of little shops, which, being inadequately equipped with machines, cannot possibly undertake any elaborate tooling operations, or accept the responsibility of a complete shell or engine. But these shops can, and do, take just some small portion or a simple element numbered by thousands, as pins, screws, base plates, some portions of fuses, a bit of pressed work, some special hardening operation, and so on. These are not controlled firms under Government supervision, but they receive their work from the big controlled shops who take the responsibility and inspect the work before accepting it. But for the assistance which has been rendered by these little shops the output of munitions could not have been carried through with so few delays.

But the strict co-ordination of details is not always accomplished. The sub-letting firms therefore have to anticipate as far as possible, and enlist ahead all the help they expect to require. Thus, there will often be an accumulation of some parts in excess of other parts completed before they can be utilized. But it is better so, rather than that the major portions of a shell or other article shall be kept waiting for some very minor element.

OBSTACLES TO CO-ORDINATION

The unexpected frequently arises to oppose the smooth onward course of production. Machines and tools may give out. Operators fall ill or suffer from industrial fatigue. Men who have acquired a valuable measure of skill or facility at set tasks are claimed for military service, and their places have to be supplied by "green" hands who have everything to learn. The chief obstacle, however, to smooth sailing lies in the failure of pieces to pass inspection. This *contretemps* is of constant occurrence. Batches of material may be defective, the defect not to be detected perhaps until some tooling has been done. Tooled portions may not conform to strict specifications. The work of the manufacturer is dogged at every stage right up to the test for the weight of the completed article. Things are not helped by the attitude of some tactless inspectors who adhere rigidly to the letter of their instructions and do not possess the practical ability to discriminate between the vital and the non-essential. Again, gauges mislead when they become worn with use and are not checked and corrected. The task of strict co-ordination is accentuated when the practice is adopted of working in shifts. Two, or three shifts are common. With the latter, no break occurs in the progress of the work, but different sets of hands will not shape exactly alike, and the output may vary slightly during each shift. Yet when it is remembered that many thousands of shops are now working to most rigid specifications, the aggregate results secured are cause for astonishment.

The Importance of the Non-Metallic Inclusions in Steel

It is impossible to manufacture steel which does not contain non-metallic inclusions to a greater or less extent. These have an important effect on its properties, particularly in producing defects and causing failures to a degree which is not sufficiently realized. Mr. A. McCance, who presented a most able study of this subject at the May meeting of the Iron and Steel Institute, states that much defective steel is bad solely because of the number of non-metallic particles which it contains, and that fully 90 per cent of the failures due to faulty material which have come under his notice are traceable to this cause alone. He states further that when material has cracked under a stress which experience shows it should safely have carried, it is advisable to examine the crack along its whole length, and when this is done, in many cases it will be found that the crack passes through groups of inclusions, while in cases in which it can be traced to its origin it is not unusual to find that it has started from a segregation of non-metallic particles. He treated a piece of steel in such a way as to produce slight intercrystalline brittleness, and then stressed it above the elastic limit. A number of small cracks appeared, and in nearly every case they started from one or more non-metallic inclusions.

He next heat-treated a heavy slab known to contain inclusions, and carried out tensile tests on pieces machined along the length in the direction of rolling, and also at right angles to this direction through the thickness of the slab. The length-test was in the same plane as the center portion of the thickness-test, so that they were in every way comparable. The results obtained were as follows:—

	Elastic limit Tons per sq. in.	Ultimate stress Tons per sq. in.	Percentage elongation on 2 in.	Percentage contraction
Length (A)	24	43.2	27.0	65.8
Thickness (B)	18	34.5	4.0	16.8

These remarkable differences in properties, particularly as regards the ductility of the steel, are due solely to the presence of the non-metallic inclusions, which in the fractured tensile surfaces of (B) appear as thin circular discs. McCance goes on to point out that these have acted as small areas of zero strength which have lowered the effective area of the test piece, though this is not the only effect they have, and he considers the distribution of stress in such a composite material. It has been proved experimentally by two different methods that the stress at the edge of a circular hole is three times that of the average. In the case of inclusions the elastic properties of which differ from those of the surrounding steel, the differences in stress at the edges will not be so great as for holes, but the edge-stress will still be greater than the average. "In steel, therefore, which possesses even slight brittleness the presence of inclusions may give rise to cracks when such material is stressed, though in steel which has received proper thermal treatment during rolling, forging, etc., inclusions, so long as they are evenly distributed and small, will have an effect which is quite negligible. It is only when they begin to form groups that they have a detrimental effect, and this power which they have to segregate is, unfortunately, without control in the existing state of our knowledge, so that the only way to minimize the chance of segregation is to lessen the number of inclusions present."

In his paper McCance considers the method of occurrence and composition of the various non-metallic inclusions and how they are formed. According to him, there is no evidence that any of them are soluble in molten steel. In other words, they exist as suspensions, and therefore do not obey the laws governing the segregation of elements soluble in liquid steel. Being lighter, they tend to rise to the surface. Assuming, as he does, that the particles exist as spherical globules (density=4), and that the viscosity of liquid steel is about the same as that of mercury, he calculates their velocity of rising (undisturbed) as follows:—

Diameter of particles	Velocity of rising
10.0×10^{-3} cm.	80 cm. per minute.
1.0×10^{-3} cm.	0.8 cm. per minute.
0.1×10^{-3} cm.	0.008 cm. per minute.

Taking for purposes of illustration an ingot of 140-cm. length, which set in twenty minutes from the time the mould was filled, and ignoring convection currents, he calculates the percentage of the number of particles of each size which would be entrapped in the solid metal thus:—

Diameter of particles	Per cent. entrapped
All over 3.0×10^{-3}	0
All over 2.0×10^{-3}	54
All over 1.0×10^{-3}	88
All under 0.5×10^{-3}	100

Convection currents play an important, though uncontrollable, part in determining both the position and size of the inclusions in every steel ingot. Inasmuch as the viscosity of the steel diminishes as the temperature rises, the metal should be cast as high above that of the liquids as is practicable.

The greater part of the paper contains a detailed study of the identification and mode of occurrence of the inclusions commonly met with, *e. g.*, manganese sulphide and its oxidation products, manganese silicates, iron oxide scales and silicates, acid and open-hearth slags and their reduction products, fluxed refractory materials, and oxide inclusions. Iron sulphide, which is scarcely ever encountered, and the action of aluminum on the sulphides of iron and manganese are also dealt with. By means of various etching reagents any inclusion can be classified as a sulphide, a silicate, or an oxide, though research is required for the working out of more suitable reagents than at present exist.

Discussing equilibrium conditions in liquid steel the author considers that ferrous oxide plays a most important rôle in determining the origin and occurrence of inclusions; the evidence shows this substance is present in the liquid. The addition of manganese in the form of ferro-manganese causes the reaction $Mn + FeO = MnO$ to take place, and the oxides so formed, if uncombined, further form inclusions. The reduction, however, is never complete. Inclusions of this type contain invariably between 60 and 70 per cent of MnO and from 21 to 28 per cent of FeO, and this is an expression of the equilibrium relations between the two oxides. Silicon and aluminum also act strongly on ferrous oxide, and to an enhanced degree as compared with manganese. The ferrous manganous oxide complex passes, if sufficient silica is present, into a silicate, and ultimately into manganese silicate only. In the author's words, therefore, ferrous oxide "is an influence for evil in every class of steel, for when it is not removed it is the cause of blow-hole formation, and when it is removed from solution it leaves as a non-metallic inclusion a record of its previous existence."

It would appear, therefore, that in the manufacture of steel the chief desideratum, if inclusions are to be kept down to a minimum, is to finish with a bath containing the minimum of ferrous oxide. This is achieved in practice by working at as high a temperature as possible, which produces not merely less oxide in the steel, but also less iron in the slag, *i. e.*, a more silicious slag, and the theoretical justification for it is clearly shown in the paper.—*Nature.*

The Carbone Method for Retting Textile Plants

Reference is made to Rossi's method (*Jour. Soc. Chem. Ind.*, 1917, 79), for the retting of hemp, etc., by cultures of a specific pectic ferment, *B. Cornesi*, which in the author's view is identical with or very similar to *B. asterosporus*. This method has given satisfactory results in Italy and France, since it shortens the time of retting, gives no bad smell, and allows inferior hemp to be retted more rapidly than in field retting pools. On the other hand, the product differs from that obtained by field retting; the green parts of the bark remain adherent to the fibers and special machines must be used for separating them and washing the fiber. The resulting material is of a different character from that of the standard product and some temporary difficulty may be experienced in disposing of the fiber to advantage. These differences are attributed to the use in Rossi's process of an aërobic bacillus, which is not a natural agent of the field retting process, having first been isolated from a decomposing potato. In Carbone's process, on the other hand, an obligatory anaërobic bacillus is employed, which was isolated from the mud of retting pits at Bologna and which has been named *B. felsineus*. This bacillus has been found fairly generally distributed in the hemp pits of Italy and is very probably the specific natural retting agent. Together with *Saccharomyces*, this bacillus actively rets hemp, in stalks or green "harl," in less than 2½ days at 37° C. It gives the same type of retting as the field retting, *i. e.*, complete detachment of the woody parts and spontaneous exfoliation. This renders the use of special machines and washing unnecessary and the manipulation is the same as in field retting. The Carbone method is being tested extensively on the 1917 crop. In applying it, pools are built, the water is heated to 37° C. by steam or otherwise, and the selected culture is used. Besides hemp, *B. felsineus* is capable of retting other bast fibers and various species of *Malvaceae* and agave.—Note in *Jour. Soc. Chem. Ind.* on a paper by D Carbone and A. Tombolato in *Annali. d' Igiene Sperim'*.

Photos by Internat'l Film Service, Inc.

A battery of electric searchlights for field work

Automobile generating outfit for operating searchlights

Military Searchlights

In the design of a searchlight, military requirements must give way to mechanical ones and the necessity of a quick and accessible source of supply for replacements must be considered. To make a light and easily portable projector it is necessary to use aluminum.

On the western front it has been found that the average time that it is possible to use a searchlight without a strong probability of losing it is thirty seconds. This, of course, is when the projector is directed on the enemy's position from a point near the first line trenches. The position of the light is readily plotted by azimuths sent in from observation stations and it takes but a moment to compute the range and azimuth from the gun, lay the gun, and fire the first salvo. Therefore it is necessary to move the searchlight instantly. If the projector is light and easily portable, this is not a difficult task; but if the light is heavy and unwieldy or is fastened to an elevating tower, which takes two or three minutes to lower and then requires that horses be brought up to drag the lamp cart away, it is certain to be lost. Only when the enemy's artillery is so busy repelling an attack that it cannot afford to waste the time necessary to destroy the searchlight is it safe to use one for any length of time on the battlefield.

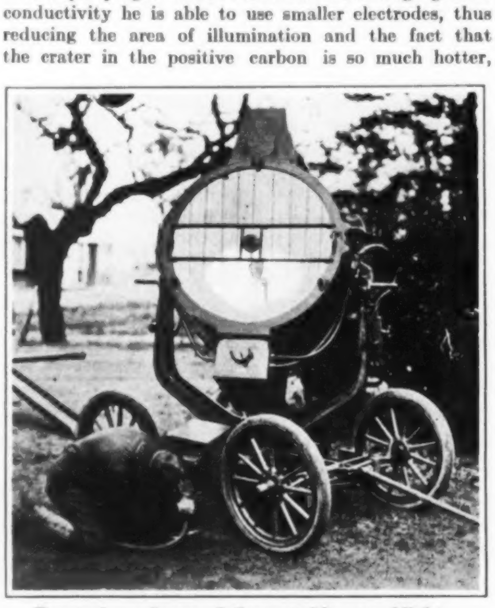
As a consequence of the fact that we must expect an effective fire a few moments after we start to use a lamp we must be prepared to obscure the lamp, move it rapidly from the vicinity and get the cable away from the spot as quickly as possible. In order to do this, searchlights are mounted on a light man-drawn four-wheeled cart. The cable is carried on a small cart of its own, and as much as possible is used in order to get the generator set sufficiently far away from the lamp so that a stray shell will not destroy it. When the lamp is fired upon, the cable is instantly withdrawn from its receptacle in the base of the lamp and the dynamo tender notified by telephone to shut off the current. The crew then withdraw the lamp as rapidly as possible. While the lamp crew are removing their lamp, the linesmen and the spare dynamo tender have seized the cable at a point about two hundred feet from where the searchlight formerly was and are dragging it toward the generator set. The dynamo tender and the non-commissioned officer in charge have gotten the automobile truck, upon which the generator set is mounted, under way and are already proceeding to a prearranged point where all parties meet to recommence operations.

The light extremely portable type of searchlight is a lamp which one man can take anywhere that a man can go. This type is carried on a two-wheel buggy which also carries the cable reels, two reels of 500 feet each which can instantly be detached from the buggy and thrown aside if the occasion requires. The lamp likewise may be detached from the buggy and carried to a place of safety by its tender.

A searchlight must not illuminate its own vicinity or the enemy will be able to spot his shots. Otherwise the spotter will lose sight of his tracers as soon as the projectile gets anywhere near the beam, and he will not know whether his fire is going high or low. He must obtain a direct hit on the lamp itself or a hit so close to the lamp that the shell will destroy it with its fragments. However, high explosive shell is not very effective in open air as the fragmentation is too small. As a consequence all the light given forth by the lamp must be condensed so as to shine on the target and the target only.

To effect this concentration of illumination a parabolic reflector is used in the searchlight barrel. Some searchlights are provided with metallic reflectors, but these, which have all the advantage of not being completely shattered by one rifle bullet, are even less efficient than the glass mirrors. The electric arcs are invariably of the horizontal type. The arc is regulated by an automatic mechanism which is intended to keep the flow of current across the arc constant.

The Sperry lamp burns its carbons faster than the ordinary type and they are in consequence very long. When intended to be used in anti-aircraft work both types of lamp are provided with a small wire screen to protect the mirror from fragments of carbons which may fall from the arc and crack or melt the face of the mirror from their intense heat. The cores of these carbons contain metallic oxides so they do not burn when heated and do not readily vaporize. The efficiency of the Sperry light is due to the fact that through greater conductivity he is able to use smaller electrodes, thus reducing the area of illumination and the fact that the crater in the positive carbon is so much hotter,



Front view of one of the portable searchlights

not being cooled constantly by the latent heat of vaporization of the liquid it contains. There is a blue color to the Sperry lamp which is troublesome in land work but is a positive advantage in marine work.

Our lamps are safe from observation by the enemy's aircraft in the daytime as we remove all sets at daylight to some point where they are certain never to be at night. Generator sets are so built that they can be taken off the truck carrying them and placed anywhere upon a spot which is nearly level and operated without the necessity of bolting them down to foundations. Their balance is such that there is no vibration at no load or full load and when used in fixed defense work they can be put in an underground casemate. The standard cable is for fixed defense work where it may be buried and will not often be moved. For portable work an extra flexible cable is used; this will stand constant reeling and unreeling. The cable carts are constructed so as to permit access to both ends of the cable thus obviating the necessity of unreeling all of it to get at the end. With non-reversible plugs, either end may be attached to the searchlight and the other to the generator set without danger of reversing the polarity. The large lamps may be used either in fixed defense or with field artillery; the small ones with infantry on advanced base work.—*From a paper by Major Howard C. Judson, in the Marine Corps Gazette.*

Switzerland Connected to the Mediterranean

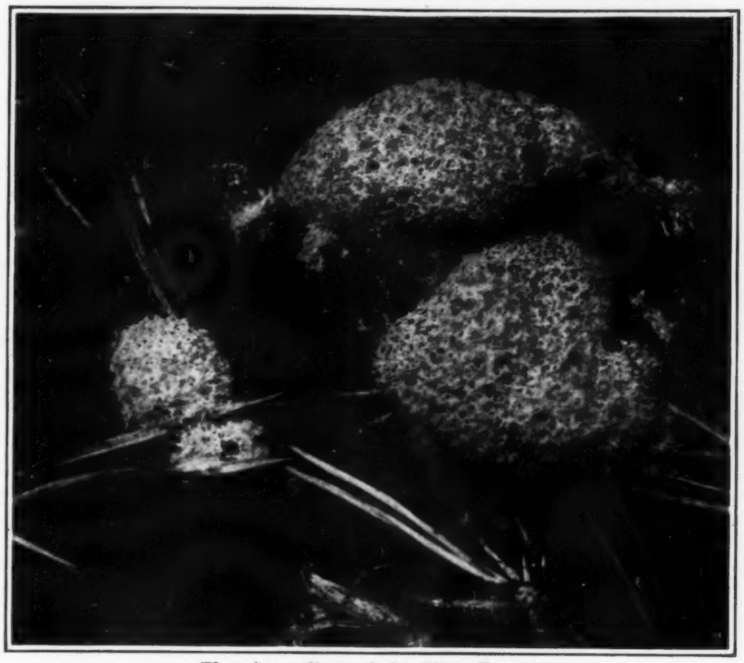
A waterway connection between Switzerland and France has been an important question for some time past, and a recent contribution to the subject is a paper read at Paris before a body of leading engineers and representatives of commercial interests, under the auspices of the French Naval League, by M. Paul Balmer, President of the Swiss Association for Navigation from the Rhone to the Rhine. This is a problem which is of great interest for the economic future of the two countries. It is also intimately connected with the project for making the Rhone navigable upon the whole or most of its course, which has been occupying the attention of engineers in both countries. M. Balmer sets forth the main lines of the project as follows: We must start with the idea that the waterway system of Switzerland is now connected to the Rhine, but that this country has no similar outlet on the French side. But it would be a great advantage to be able to make suitable connection with the Rhone, and it is this idea which is to be promoted at the present time. Engineers consider that it is quite feasible to do this, and in fact the question is not one of recent date, but has been under examination for a long time since, and the great economic advantages which the two countries could obtain in case the Rhone were made navigable have been already exhaustively considered and clearly pointed out.

In Switzerland, the waterway from Bale to Geneva already exists, and it now remains to make connection on the French side between Marseilles and Geneva by way of the Rhone. Engineering work on this river consists in the construction of locks all the way along at the proper distance, up to within a short distance from Geneva, then comes the important work on the stream commencing with the great barrage proposed at Genissat, and this will solve the problem of navigation from this point to Geneva, at the same time employing the power of the Rhone for the great 300,000 horse-power project to which we referred before. This electric station, it will be remembered, will rank among the most important in Europe. The Rhone is now very narrow in many places in this region, but the proposed engineering work will open it up for navigation as far as Geneva. This will be the final step to be taken in making the Rhone navigable throughout its course, and it will thus be joined on to the Swiss waterway system. Bale or Basle will then be placed at practically an equal distance from the northern port of Rotterdam on the one hand and the southern port of Marseilles on the other, and the Swiss river system will be connected with France through the Rhone. The events of the war seemed to show to what a great degree the commercial relations between Switzerland and France could be increased, even with the present limited transportation resources. For instance, traffic between the Mediterranean port of Cette and Switzerland—this port handles much of the Swiss freight—was only 50,000 tons, while in 1916 it had increased to 500,000 tons. What is needed at the present time is the proper legislation, in order to carry out the project, which will surely be of great benefit to the commercial relations between the two countries.

Plant or Animal?

By S. Leonard Bastin

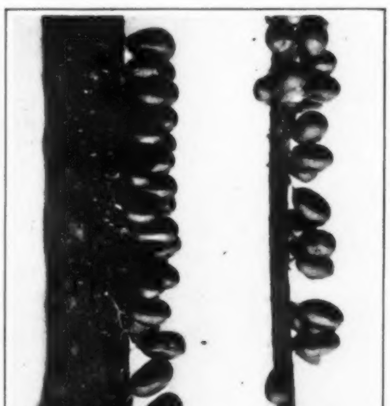
There are few more singular organisms in the world than the Slime Fungi (Myxomycetes). Although it seems strange to say so, these curious beings have never yet been definitely classed as plants or animals. Cooke and Massee, the well known British fungologists, have claimed the Myxomycetes as fungi. On the other hand, Lister wrote a monograph of the Mycetozoa in which he classes the Slime Fungi as animals. The remarkable fact is to be noted, however, that Lister's collection of Slime Fungi are placed in the *botanical* gallery of the London Natural History Museum.



The plasmodium of the Slime Fungus

A typical Slime Fungus is illustrated on this page. This is known as Badhamia Utricularis and, in its ordinary state, it is a gelatinous mass of a deep chrome yellow color, spreading over rotten wood in damp weather. When in this condition, known as the plasmodium, the Slime Fungus is simply a mass of naked protoplasm; such a huge aggregation of living matter is quite unknown in any other group of organisms. At this stage the being behaves in a most singular manner. The Badhamia feeds on living fungi and it has the power of moving towards its prey. Thus, when food material is in the vicinity, the Badhamia at once starts to flow over it. Small pieces of the Fungi are enclosed in vacuoles in the protoplasm and digested; the useless remains being disgorged and left behind on the track. The manner of feeding here described, which involves the taking up of solid food into the body and then digesting it, is quite unknown among plants. In its behavior at this stage the Slime Fungus goes on just like an animal. The plasmodium of the Badhamia is attracted to damp parts and moves also towards the darker quarters.

After a while a marvelous change comes over the Slime Fungus. The time has come for fructification. At certain points the protoplasm accumulates, and finally a stalked process is formed. While this business is going forward the Myxomycetes seeks the lighter and dryer positions. The stalked processes are practically sporangia seeing that, when they burst open, they distribute immense quantities of spores very much after the manner of fungi, mosses and ferns. When these spores alight upon a damp surface of decaying vegetable matter they germinate and there appears on the scene a speck of living jelly—not unlike an Amoeba, one of the lower forms of animal life. Quite soon a lash-like extension is developed at one end and this part moves forward, the hindermost portion following. If the organism should come across any bacteria it is quite likely to flow around them and digest them. Then the nucleus divides into two the division extending across the rest of the jelly so that finally there are two Amoeba-like organisms instead of one. Scores, or hundreds, of the beings may divide in the same way and repeat the process at a later date. This process of division goes on for a few days when the organisms withdraw all their lashes and amalgamate themselves into one mass of jelly. This represents the plasmodium state of the Slime Fungus. So the life cycle of this strange organism is completed.



Sporangia of the Slime Fungus

Bad Bromides

Nearly all photographers make bromide prints; a minority make good ones; more make passable ones; and the remainder make poor ones. The worst of it is that those who make the poor ones do not realize how poor they are. One of the greatest factors in the production of bad bromides is the idea that a thin negative is necessary, a thing which has become such an obsession with some workers that they go on making thin negatives and then seek for "contrasty" paper to print them on. This is quite an unsound way of working, for any paper which produces a print in a different scale of tones from the negative is not so likely to give an accurate rendering of the tones of the original subject. Some sort of a print may be made from almost any kind of negative on bromde paper, but a good plucky but not over-dense negative which will give a good platinum or carbon print will give the best class of print in bromide. Two points necessary to be observed whatever class of negative is being used are correct exposure and full development. These, ensure a bright print of good color which will give a satisfactory sepia with either sulphide or hypo-alum toning. The usual practice of bromide printers in portrait studios is to give a long exposure and then to develop for a very short time, often hardly relinquishing their hold of the paper while it is in the solution. Thence it is transferred without rinsing to the fixing-bath. Such prints are usually lacking in brilliancy; instead of being a pure black they usually have a rusty tint, and if toned yield the "ginger" hue which disgraces so many show cases. To ensure correct exposure it is only necessary to make a few test strip exposures ranging, say, from two to thirty-two seconds, from three or four typical negatives and to develop these fully out, or at all events for a fixed time, say two or three minutes. It will then be easy to discover from the strips the correct exposure for each class and to note it on these typical negatives, also noting the exact distance between the light and the printing frame. There are many self-satisfied printers who would be quite surprised in the improvement in the quality of their output if they would but work on this system.

Except for very thin negatives it is best to omit bromide of potassium from the amidol developer, which is, in our opinion, the best one for bromide work. M. Q. has the advantage of durability and it also avoids stained fingers, but it does not yield the pure blacks and grays given by amidol, and prints developed with it do not tone to such good colors as amidol-developed ones do. The greater lasting power of metol-hydroquinone is in itself a danger, for there is always a risk of using it with occasional strengthening long after it has absorbed an undesirable quantity of bromide from the prints previously made in it. This is indicated by the hardness and greenish color of the prints. Amidol becomes exhausted more quickly and at this stage gives poor rusty-colored prints. Different samples vary considerably in their developing power, so that it is impossible to say how many prints a given weight of the salt should develop properly. It is false economy to overwork the developer especially at the present price of bromide paper. Except when it is necessary to stop development instantaneously, prints should always be rinsed before fixing. Amateurs and those who only develop a few prints occasionally may perhaps disregard this precaution, but when a large number of prints is made daily and the bath not renewed very frequently there comes a time when the character of the fixer is changed, and muddy-looking prints result. There is no gray fog such as is caused by exposure to light, but the whites have a dingy tint which is best described by comparing them with the white of an egg which has not quite reached the election stage.

Although pyro-soda has been occasionally mentioned as available for the development of bromides, there is one point which has not yet been fully appreciated, and that is its power of producing vigorous prints on ordinary paper from flat, thin negatives. Any ordinary formula may be used, but should contain at least 40 grains of sulphite per ounce of mixed solution. A convenient way of adding the extra sulphite is by diluting the concentrated solutions with a 5 per cent solution of sulphite of soda instead of using plain water. Toning troubles are few with properly made prints, but there is one which must be specially guarded against—namely imperfect washing before bleaching. A slight trace will cause a general reduction of the image, while uneven washing, leaving a considerable quantity of hypo in places where prints have hung together, results in a patchy appearance, some parts almost disappearing, while others tone to a good color. Weak sulphide solution is another common cause of bad tones. It has been stated that, given sufficient time to act, a weak solution will answer as well as a stronger one, but that has not been our experience. We have found that even with quite weak prints a good brown tone, not orange, can be obtained with a solution made as strong as the paper will stand without blistering. Of course, there is no accession of strength, but the color is good: on the other hand, a weak solution gives a poor color to even a vigorous print. With regard to the bleaching, we have found the best tones to be obtained by a bleacher which worked rather slowly, taking, say, five minutes to bleach a fairly strong print.—*British Jour. of Photography.*

Hardening Copper

The popular interest in the so-called "lost art" of hardening or "tempering" copper is evidenced by the numerous inquiries on this subject received by this Bureau, together with samples of copper treated by some "secret" process in the endeavor to render the metal similar or equal to steel in many of its properties. The rather numerous patents covering such processes may also be cited as evidence of the interest in this field. The following may be quoted as typical:

"Heat the copper to 260° to 315° C. and subject it while hot to the fumes of burnt sugar and animal fat at a temperature below that necessary to form carbon monoxide."

There are but two well recognized methods for hardening copper: (1) By mechanically working it, and (2) by the addition of some alloying element. All of the samples of so-called "hardened copper" submitted to this Bureau showed that the superior qualities which were attributed to them were due to one or both of these causes. One method, used more frequently than any other, is to manipulate the melting of the charge so that the metal when cast is thoroughly impregnated with cuprous oxide, which renders the metal quite different from the purer copper in its mechanical properties. Inasmuch as cuprous oxide alloys with metallic copper in exactly the same sense that some other metals do, such a product is properly to be considered as an alloy and thus should be included under the second cause given above.

Gowland (183) makes the following authoritative statement regarding the "tempering" of copper as practiced by primitive peoples. "The castings (knives, swords, etc.), generally were hammered at their cutting edges and it is to this hammering, and to it only, that the (increased) hardness of the cutting edge is due, and not to any method of tempering." Most of the "copper" tools and knives of ancient origin contain considerable amounts of tin introduced by the smelting of mixed ores of the two metals so that resulting alloy can not fairly be compared with copper. Gowland further states "that the ordinary bronze of today can be made as hard as any, in fact harder than most, of prehistoric times by simple hammering alone."—Bureau of Standards Circular, No. 73.

Modern Aeronautics—II*

A Review of Some Outstanding Problems

By Dr. W. F. Durand

[Continued from Scientific American Supplement, No. 2226, Page 131, August 31, 1918]

Another problem connected with the engine is that of the carburetor. At the start of aeronautic engineering the carburetor natually took its initial form and arrangement from the already fairly well developed automobile engine carburetor. This was but natural since both engines are of the same type and both use the same general form of fuel. In respect of the conditions of operation, however, there is a marked and important difference. The automobile operates at or near a fixed level and hence in an atmospheric medium of sensibly fixed pressure and density. With the airplane the case is very different. The latter may change its level by thousands of feet in a few minutes or even seconds, as in vertical or nearly vertical dives, rapid spirals or other maneuvers.

This difference in the conditions of operation introduces a factor of distinct significance and of great importance in the design and disposition of the carburetor. Experience in the air has clearly shown the importance of this new factor, and it is not too much to say that the problem of the entirely satisfactory carburetor, capable of automatically answering to the various atmospheric conditions under which it must work, is distinctly an outstanding problem. It is true that much progress has been made and as the result of laboratory research, checked by actual experience in the air, we now know much better than, say two years ago, the fundamental conditions which must be met by the carburetor for the aeronautic engine. The present solution can hardly be considered as final however, and we may fairly admit that the whole problem of carburetion, including the manifold supply of the carburetted mixture to a multi-cylinder engine, should as soon as may be, receive a thorough and fundamental re-study in the light of the information to be drawn from the experience of the past three or four years.

Ignition

Another problem which we should view as outstanding is that of ignition. It is true that ignition, as now realized with the best equipment, seems to be fairly reliable and effective. But the whole program is open to the objection of requiring an entire electric power plant of a highly specialized type, together with electric conductors and the spark plug for producing the spark between the discharge points within the cylinder. This ensemble comprising electric generator or magneto, electric cable, distributor for sending the spark with proper timing to the various cylinders and spark plug with discharge points within the cylinder, represents a very complicated and highly specialized device for producing the initial ignition within the body of compressed fuel mixture. In its present state it is a marvel of scientific and technical development, and it does its work; but it is complicated and subject to many possible modes of derangement, and, as we all know, has been and still is the seat of some of the most serious of the engine difficulties to which the power plant as a whole is subject.

I have never been able to persuade myself that this exceedingly complicated and specialized auxiliary equipment was to be the final solution of the problem of producing ignition in an internal combustion engine. If we can anticipate the explosion engine of the year 1968, assuming that our grandchildren are still dependent on hydrocarbon fuels at that date (and furthermore that they are still available) it would seem as though some more direct and simple mode of initiating the combustion in the cylinders would have been found. Still, otherwise, we may say that on the law of probability, the chances are overwhelmingly against our having at the present moment developed the very best method of ignition. The laws of physics and chemistry, by a probability which almost reaches certainty, contain some potential combination of factors which will permit of eliminating much of the complexity and delicacy of adjustment which is so characteristic a feature of the present mode.

It is perhaps proper to add here that studies in this direction have already been made, and with results which offer promise of interesting developments in the future. The path of perfection is likely to be not a short one, however, and we can see no prospect of a development in the tomorrow of progress likely to displace electric ignition. There must, however, be some better way, and if not tomorrow, then some other morrow should see it made available for use.

*From the *Aeronautical Journal*.

The problem of ignition is then one which is distinctly outstanding, one which by its importance merits the most careful study, and one which offers at least reasonable ground for hope of a successful and relatively simple substitute for the present mode.

Maintenance of Power at High Altitude

We come now to a problem of the very highest present and future importance, that of maintaining the power of the engine at high altitude.

The situation as it develops in the case of an airplane mounting to higher and higher levels in the atmosphere is readily appreciated with a moment's thought.

The power of the engine arises from the combustion of vaporized hydro-carbon fuel. The power per cycle for a given cylinder will therefore, to a first approximation and assuming a sensibly constant efficiency of thermodynamic transformation, vary directly with the weight of the fuel which can be burned per cycle. But this in turn depends upon and is conditioned by the amount of oxygen which can be drawn into the cylinder per intake stroke of the cycle. But the oxygen is brought in as one of the constituents of the atmosphere and hence the amount of oxygen available per intake stroke will depend upon and be directly proportioned to the amount of air which can be drawn in. But in terms of volume, just a cylinder full, or more exactly, just the volume represented by the piston displacement in moving from one end of the stroke to the other, can be brought in. Hence, we may at least depend on what we may term a cylinder volume of air no matter where we are. But just here arises the trouble. The actual weight of air depends conjointly on the volume and on the density, and unfortunately for the aeronautic engine, at least, the density of the atmosphere decreases steadily with altitude, so that at 15,000 feet, for example, the density is only about 60 per cent of the normal density at the earth's surface. It is clear then that an aeronautic engine, other things equal, will draw in at this altitude, per intake stroke, only about 60 per cent of the weight of air as compared with the indraft at the earth's surface. Hence, it will be able to burn only 60 per cent of the fuel and with equal efficiency will develop only 60 per cent of the power.

But here we must stop for a moment and inquire as to the effect of such reduction of power on the speed of the airplane. We know that, other things equal, the resistance of an airplane to propulsion through the air at uniform speed varies directly with the density of the medium. Hence, at the same speed as near the surface of the earth and with the same attitude or angle of attack, the aeroplane at 15,000 feet elevation would experience only 60 per cent of the resistance and would require only 60 per cent of the thrust, and at constant revolutions of the propeller would require only 60 per cent of the power from the engine. Hence, it appears at first sight as though we had lost nothing in speed by the reduction of the power of the engine. If the latter has been reduced to 60 per cent of its amount at low levels, so has the resistance and power required, so that the speed realized should remain the same.

Such would, indeed, be the case if this were all of the story; but, unfortunately, other considerations enter and the simple relation of uniform speed at varying altitudes cannot, as a matter of fact, be realized without compensating features.

Thus, if at a constant speed and constant angle of attack for the wings, the resistance to propulsion is only 60 per cent as great at the altitude of 15,000 feet as on the ground, it is, unfortunately, the same for the lifting force developed by the wings. This also is only 60 per cent as great, while the weight of the machine remains sensibly constant at all altitudes. Let us pause long enough to grasp clearly this fact, that while, at constant speed and angle of attack, the resistance, the lift and all other aerodynamic forces involved vary directly with the density of the air, and hence decrease with the altitude, the weight of the machine, and hence the lift necessary for support, remain sensibly unchanged. Hence, at the same angle of attack the lifting force at altitude and under the same speed will no longer support the plane, and unless something is done, it would be unable to maintain at such speed continuous horizontal flight.

Two courses are then open for consideration, as follows:

(1) We may seek to increase the speed until at such increased value the lift will equal the weight of the plane. Under the conditions assumed, this would involve an increase of speed of about 30 per cent, thus increasing the resistance to propulsion by nearly 70 per cent or bringing it back to its value at low altitude. But this resistance overcome at the increased speed would mean an increase in the required horse-power of 30 per cent as compared with that normally developed at low level, while with the actual indraft of air and even allowing for the increased speed, only some 78 per cent of this, or 60 per cent of the needful amount would be developed. Hence, no such speed could be realized and the support of the unvarying weight in the rarefied air cannot be obtained in this manner, and must be sought otherwise.

(2) Instead of seeking for the necessary lift by increased speed we may seek it by changing the angle of attack; by changing the flying attitude of the plane so that at the same speed, for example, the lifting force will be greatly increased. In this manner the needful lifting force may indeed be realized. But unfortunately with the increase in lifting force will come also an increase in head resistance, not necessarily in proportion, but still a definite increase. This will mean that the actual resistance at, say, 15,000 foot elevation will be greater than 60 per cent of that at low elevation and hence with 60 per cent of the power available per cycle, the original number of revolutions cannot be maintained and a reduction in speed will result. With this reduction in speed will come a further loss in lifting effect and need for a further change in the angle of attack with increased head resistance; until finally, at some reduced speed, a condition will be found where the needful support for the weight of plane may be realized and the resistance to propulsion can be met by the thrust or pull developed at the propeller. Under these conditions, horizontal flight again becomes possible, but at a speed somewhat below that corresponding to low altitude conditions.

But this is not all of the story. In addition we must reckon on a diminished efficiency of the engine with decreased power, and with the probability of a loss in propeller efficiency with the resultant change in speed. Thus, if an engine is primarily designed to work at its best efficiency and under its best conditions at or near full atmospheric pressure and density, it will not work with equally good efficiency at high altitudes in rarefied air and when developing only about one-half the power for which it is primarily designed.

All of this means, in brief, that at an altitude of say 15,000 feet as compared with low levels, the plane must fly at a less advantageous angle of attack and hence with more resistance; while the engine will be able to burn only about 60 per cent as much fuel and may transform the resulting heat less effectively than when at low altitudes. Hence, the power developed may be somewhat less than 60 percent, and thus insufficient to maintain the same speed; and with diminishing speed there may be further loss of efficiency in the propeller and a further loss of speed until finally matters become adjusted at some value usually definitely and sometimes considerably less than that corresponding to low level conditions.

Hence, as an overall practical result an airplane normally loses horizontal speed as it ascends to higher altitudes.

Confronted with this fundamental fact, what is to be done? Such loss of speed, especially in a military sense, is or may become very serious, and one of the large and definitely outstanding problems in aeronautic engineering at the present time, centers about the possible ways and means of meeting this condition.

The obvious proximate solution is to avoid, so far as may be, the decrease in the amount of air handled per intake stroke of the piston as the plane ascends to higher and higher altitudes.

Broadly, two courses are open. First, we may definitely and frankly design the plane and engine for a certain desired performance at a given altitude, say 15,000 or 20,000 feet. This is a straightforward problem in aeronautic engineering. Given the desired schedule of operation and the altitude, we can determine the resistance to be overcome and the horse-power required, and can design the engine accordingly. In such case the volume of the cylinders will be suited to the rarefied air in which the engine is to work and all proportions and details will be worked out on this basis.

It will be obvious that such an engine will have much too large a piston displacement volume when at low

altitude. That is, it will be over size and over powered relative to the plane. In fact, operation near or on the ground under the same adjustments as at altitude would be quite out of the question. Means must therefore be provided for reproducing, when on the ground or at low altitudes, substantially the operating conditions at high altitudes and low air density; that is, the conditions for which the engine was designed. This may be most conveniently done by throttling down the air intake so that while air at or near full sea level density may surround the engine, it will be reduced in pressure at the intake throttle to such a degree that the amount actually taken into the cylinder will only equal that which would normally enter, without throttling, at high altitude.

On the other hand, we may definitely design the engine for operation at or near sea level and with size of cylinders and all proportions and adjustments worked out accordingly, and then by a supplementary device endeavor to maintain or to nearly maintain such conditions within the engine itself, even if it is at high altitude and surrounded by air of a lower density.

This solution calls for some supplementary form of compressor or equivalent device which shall operate on the rarefied air as a first stage and raise it from the low pressure, characteristic of the altitude, up to or nearly to normal low altitude pressure and density.

Each of these alternatives represents a perfectly possible solution. Each has its special advantages and disadvantages. Each has its advocates as a solution of this important problem.

The first solution is the simpler of the two, since it involves no special or additional device for compressing the air. It does, however, mean extra weight in the engine which is always there and which will reduce correspondingly the net carrying capacity of the plane.

On the other hand, the compressing device of the second solution is not easy to realize satisfactorily and it also involves extra weight, though presumably less than in the case of the first solution. Again, its operation as a separate or independent unit for realizing a preliminary compression of the air is less efficient than to do the whole compression in the engine itself and by the engine piston as in the first solution. Only extended and careful trial will presumably be able to finally decide which is on the whole the better solution of the two.

The reserve necessary with regard to military matters makes it unwise to attempt to give any account on this occasion of just where the matter stands with regard to this problem; but it will at least be safe to note that it is a problem which is attracting much attention and study on the part of the various allied Governments, and that much valuable information is being developed, on which we may hope that some satisfactory solution may be based.

THE AIRSCREW

We shall now turn our attention for a few moments to one of the most intricate and hence one of the most interesting of the many problems presented to us by the aeronautic art; that of the airscrew or propeller.

The function of the airscrew is, of course, to take the torque of the engine and to transform it into a propulsive thrust; or otherwise to take the power given by the engine to the crank shaft and transform it into driving or propulsive power for the aeroplane. The problem is further complicated by the fact that expressed in terms of a power relation, it is not simply the question of an engine handling so much power over to the airscrew for the latter to transform into propulsive power. Instead, the power which the engine itself can develop is dependent on the propeller and likewise on the aeroplane to which they are both attached. We have here, in consequence, a series of complicated implicit relations, and from which the propulsive characteristics of the plane-propeller-engine combination take their origin. In fact, it must never for a moment be forgotten that the moving aeroplane is in effect an aeroplane-motor-propeller combination and that no one of the three can be determined independently of the other two.

Without entering into any detailed discussion of this problem, it will be clear that the airscrew will exercise a controlling influence on the power which the engine can develop. Thus, it is evident that an aeronautic engine, in order to develop power, must be permitted to move its pistons, to revolve its crank shaft, in other words, to make revolutions; and other things equal, the power developed will vary directly with the revolutions which are realized. Again, it is easy to see that the size and amount of surface of the airscrew blades will present a controlling feature regarding the revolutions which *can* be realized. Thus, the airscrew may be enormously over size, too large in diameter and presenting a large and unwieldy surface to the air. Suppose this to be the case with a plane of size suited to the airscrew but not to the engine. That is, the engine is far too small for either airscrew or plane. In such case the engine simply will not be able to make its normal number of revolutions. It will be held down by the excessive resistance to rotation presented under such circumstances, and may thus develop far less than the normal power of which it is capable under proper conditions. Many other combinations may occur which we cannot stop to discuss or even to mention. Broadly speaking, the plane, the engine and the airscrew, as the propelling agent, form a most closely knit combination and each interacts in a more or less controlling manner on the operation of the other two.

In order even to make a start with the problem of the airscrew it is therefore necessary to assume conditions regarding both the plane and the engine. If these conditions, as assumed, are then realized in practice and if the design has been well carried out, the anticipated results may be reached. If, on the other hand, the assumed conditions are not realized as regards the plane and the engine, then no matter how well the design of the airscrew may have been carried out, the anticipated results will not be realized. Hence, no matter how good the airscrew may be by itself, no matter how carefully designed and constructed, no matter how faithfully it may be able to realize the conditions for which it is designed, if these are not the conditions under which it is actually placed for service, the results economic and otherwise will be unsatisfactory; not necessarily by reason of any fault in the airscrew as such, but due simply to its lack of adaptation to the conditions of operation. An effective airscrew is therefore not only one which is properly designed and constructed in itself, but also one which is permitted to operate under the conditions intended and contemplated in its design.

All this is, of course, well known, and if I have taken the time to repeat these well-known facts, it is the more clearly to bring to our minds at the present moment the fact that the airscrew represents not only a problem in itself, but also one of adaptation to and of usage with the proper combination of plane and of prime mover.

The general problem of the airscrew is by no means, however, to be classed distinctively, as outstanding. Instead, an enormous amount of work has been done on it, both theoretically and experimentally, and in its main features it has been brought fairly within the limits of a solved problem. There have been three modes of approach, briefly, as follows:

(1) The analysis, geometrically, of the blade of an airscrew into a series of elements, occupying each a narrow strip running across the blade from leading to following edge and making up, by their summation, the blade as a whole. Each of these elements or strips is then considered as, in effect, a little elementary aerofoil and for which the usual aerodynamic characteristics are readily determined, either by direct experiment on a model, or by selection or interpolation from and among the large amount of available data regarding such aerofoils which have already been summitted to experimental investigation. With such data in hand relating to the series of elements going to make up the blade, it is a matter of simple computation to combine them in such manner as to represent the action of the blade as a whole, under the conditions assumed, and thus in general terms the problem is solved.

(2) A law of similitude is assumed and a small model propeller is tested out experimentally and under conditions which permit, under the law of similitude assumed, the translation of the *observed* results for the model into the *probable* results for the full sized airscrew.

(3) Full sized airscrews are tested out as nearly as may be under flying conditions and are made the ultimate basis of design.

The limitations of method number 1 arise from the following:

(*a*) The coefficients derived for aerofoils correspond to straight line motion between the air and the foil, whereas, in the airscrew, the relative motion is in a helical or spiral path.

(*b*) The actual velocities for which such coefficients are derived are usually for speeds not exceeding 60 or 70 miles per hour, whereas the actual speeds of the tip elements of airscrew blades may move at speeds of 500 m.p.h. and upward. The extent to which the usual square of the speed law may be extended to such values is not as yet fully known.

(*c*) The coefficients used are derived for the various aerofoil sections or elements individually, whereas, in the actual airscrew, they all act conjointly or collectively in making up the airscrew blade.

Application of method No. 1 cannot therefore be made except in so far as it is justified by actual and final experience on full sized forms under flying conditions.

Method No. 2 (that with reduced size models) has the limitation that the law of similitude employed is, of necessity, not exact but approximate and the degree of reliance which can be placed on results thus found can again be determined by ultimate reference to full sized forms under flying conditions.

Method No. 3 (that with full sized forms under actual flying conditions) has the limitation of very high cost, both in equipment and time, and as a result of which only a relatively small number of forms can actually be subjected to adequate test in this manner.

Again, method No. 1 (that of computation based on coefficients determined by laboratory experiment) has the advantage of requiring only a pencil and pad of paper with a table of predetermined coefficients. No. 2 (that with the small models) has the advantage over No. 3 of relatively small cost, of permitting the tests to be carried out in a wind tunnel with all conditions under control, and finally it permits of carrying quickly through the test program a very large number of types and forms. It should perhaps be stated here that as between methods No. 1 and No. 2, the latter is accepted as much the more reliable of the two. In fact, it is not too much to say that when used with judgment it furnishes a very satisfactory and well-nigh universally accepted method of dealing in a laboratory way with most problems of airscrew design and operation.

[TO BE CONTINUED]

The Katanga Railway

THE recent completion of the section of the Katanga Railway to Bukama, on a navigable portion of the Upper Congo River, represents an important addition to the line which may some day realize the dream of a through railway route between Cape Town and Cairo. There is the further promise, now that the Suez Canal has been bridged, of forging a rail link between the African and Asiatic railway systems, but a great deal of work remains to be done before any such hope can be realized. The completion of this project would involve the construction of a large mileage of railways, and there is also the difficulty of break of gauge to be overcome.

The carrying of the railhead to Bukama enables the through journey to be accomplished from Cape Town to Boma, the capital of the Belgian Congo, via Bulawayo, Elizabethville, Stanleyville and Matadi. The total length of the new section of railway is 450 miles, and it has taken the British contractors for the Compagnie du Chemin de Fer du Bas Congo eight years to construct it. The difficult character of the country traversed, involving many heavy embankments and cuttings as well as the construction and placing in position of numerous bridges, the difficulties of obtaining materials, and scarcity of labor, have served to prolong the operations; but in view of the heavy character of the work generally the contractors have completed the contract in as short a period as could be expected, particularly having regard to the fact that nearly half the mileage has been constructed during the war period. The gauge of the railway is 3 feet 6 inches, and 60-pound rails are employed throughout. Steel sleepers have been used, as timber sleepers would be quite unsuited to the climatic conditions and would be unable to resist the attacks of insects. Only in the case of the final section approaching Bukama was it possible to work from both ends, and the work was there pushed forward with greater speed than was practicable in the earlier stages of construction, notwithstanding the fact that some of the heaviest bridges and the longest cuttings and embankments were included in the route.

Present requirements for engine power are being met by 45 locomotives of the non-superheating type, all designed to burn wood as fuel. The original contract was for 14 locomotives of the 4—8—0 type, three of the 2—6—0, and four of the 2—6—2 type, but these have now been reinforced by 24 locomotives of the Mikado type, 2—8—2, having a total weight in working order of 75 tons and a load per axle of 14 tons. The passenger stock includes ordinary and dining cars, and the goods stock 300 wagons of 35 tons capacity for the ore and fuel traffic, and 355 wagons of various types. All rolling stock is equipped with vacuum brakes, and the passenger cars are electrically lighted on the Stone system. The principal stations are also lighted by electricity, and the necessary shops have been provided for ordinary repair and upkeep work.

For the moment, perhaps the Belgian owners of the railway will be content to rest on their achievement in reaching Bukama, but it is certain that contracts for further mileage will be given out as soon as conditions permit. Meanwhile other lines of the railway system of Central Africa are being investigated, including a line from the Katanga to the Lower Congo via Luebo, and another to link up with the Benguella Railway in Portuguese Angola.—Engineering Supplement of the *London Times*.

Apparatus used for restoring foot and leg movement. It consists of two boards 14¾ feet long and 4 inches wide, placed about 8 inches from a wall in a slanting position so that one end is 6 inches from the ground and the other 2 feet from the ground. This contrivance is designed for the joint movements of legs which have become stiff. The patient puts the affected limb on the board and taking short steps moves it gradually as far as he can bend it.

Apparatus used to improve the patient's ability to walk. It consists of 2 parallel rows of little pigeonholes placed end to end and varying up to 25½ inches long by 5¾ inches wide by 4 inches high. The patient walks along placing each of his feet in the pigeonholes while keeping clear of the board between the two rows. There is also a board lying on the ground which indicates all the compartments 19½ inches in length, as in the reëducation of sufferers from tabes, which are the places to put the feet when walking normally.

Mechanotherapy to Aid Injured Soldiers

In many cases of injury to soldiers in the war, either from shock, or direct wounds, one of the results is the loss of the use of a muscle, or of a limb through its becoming stiff. In former days such misfortunes, which are frequently of a serious nature, meant permanent disability; but of late considerable study has been given to the subject, with most gratifying results. Surgical treatment is employed where necessary, but to a great extent the process of rehabilitation consists in methods designed for gradually producing suppleness in a stiffened joint, together with the reëducation of muscles that have forgotten how to work, or to coordinate, through the result of injury or long disuse. And as these various processes may be with advantage carried on during the period of the convalescense of the patient not only is no time lost, but the exercises tend also greatly to improve his general physical condition. The photographs, together with their accompanying explanations clearly indicate the methods and the apparatus employed successfully in France. The simplicity of the system is clearly apparent, and one of its special merits is character of the apparatus employed, which is constructed of ordinary materials that can be picked up anywhere, and requires practically no skilled labor to build and set up.

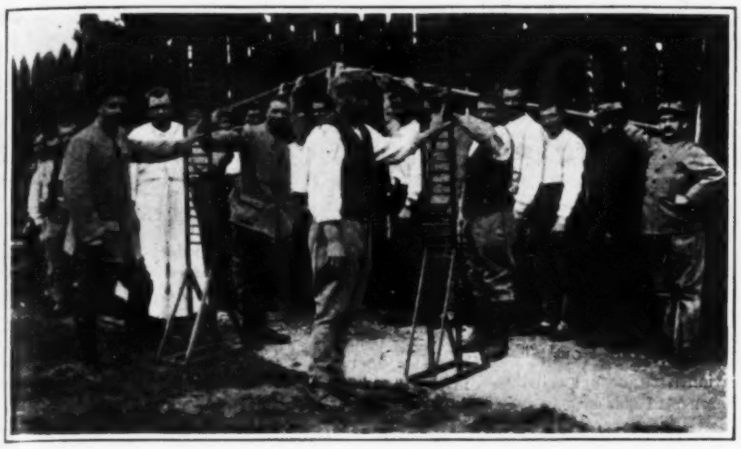
Electricity Recovering from Electric Traction Lines

As soon as electric propulsions of vehicles was introduced, the fact was recognized that an electric motor, when not actuated by the supply current and not turning the car axle, but when itself turned by the axle on going down hill, is converted into a generator which sends current back into the system and exerts a braking instead of a propelling effect. When electrical engineers had convinced themselves of the reality of the effect, which had been foreseen, of course, the possibility of recovering or regenerating electric energy on mountain railways became one of the arguments in favor of electric power versus steam power on such lines. It was soon found, however, that the apparatus necessary for the recovery and safe operation complicated the machinery on the locomotive and in the power house. The experience gained on the first line on which recovery was attempted—the Giovi railway leading from the Apennines down to Genoa—was hardly encouraging, and when less than ten years ago it was decided to adopt electric propulsion on the Gotthard Railway, experts were against electricity regeneration. The decision might have been different, if the regeneration had not, at that time, appeared restricted to three-phase working which was considered unsuitable as it necessitated a double line of conductors. Meanwhile, noteworthy progress has been made in this domain, chiefly in the United States; different current systems of traction have been adapted to regeneration, and the modification of the electric service on the Gotthard line, we see from an article by Professor W. Kummer, in the *Schweizerische Bauzeitung*, comprises experiments on this point. Considering mainly traffic conditions, Kummer concludes that, with a fairly frequent train service, the recovery should prove economical, especially where coal is expensive, and even in cases where the primary power is hydro-electric. The electric problems at issue were very ably discussed last year before the American Institute of Electrical Engineers by Mr. R. E. Hellmund, of the Westinghouse Electric Company. Hellmund distinguishes resistance braking, when the current generated by the motor is absorbed by resistance on the vehicle, regenerative braking when the current is returned to the supply system, and combinations of the two methods, and he explains how the problems can be solved and have been solved in various ways for different systems. With three-phase working hardly any additional apparatus are required, except that rotating converting devices (such as frequency changers) might be overspeeded on down gradients when supply is interrupted; over-speed relays, used for similar reasons with synchronous converters, help over that difficulty. The phase-converter system (single-phase line and induction motors) offers very similar, simple problems; this system is in use on the Norfolk and Western Railway, and was in fact adopted there, because it promised current regeneration. The direct-current series motor cannot as such be used as a generator; but with the aid of separate excitation, constant or variable, successful solutions have been worked out on the Lake Erie and Northern Railroad (working pressure 1,500 volts—2,000 volts maximum during regeneration), and on the Chicago, Milwaukee and St. Paul Railroad, the biggest electric railway of the year 1915, at any rate, 440 miles long. The two motors of a locomotive are on that line coupled in series for 3,000 volts. The alternating-current commutator motor system avoids the flashing difficulty of direct-current motors, but introduces other difficulties, which can be solved in various ways, however, more satisfactorily than was done on the Midi Railway in France. Hellmund's conclusion was that regenerative braking would soon assume great commercial importance for heavy railway work and would win over some railways, now operated by steam, to electric propulsions.—*Engineering.*

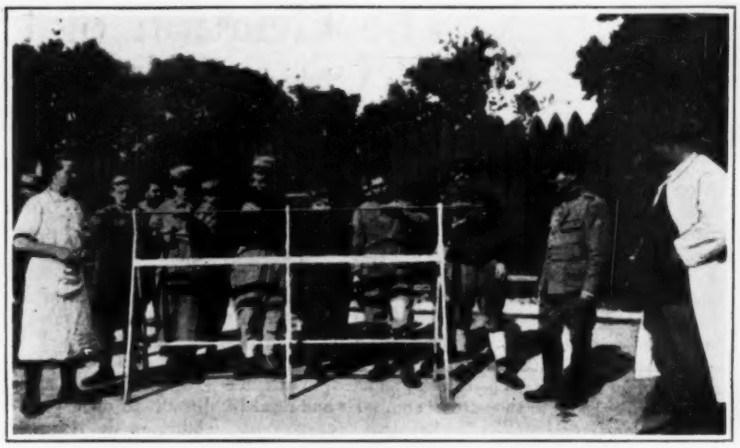
Rehabilitating the muscles of the arm and shoulder. Two uprights are set up in the ground close together, and a wooden bar is pivoted between them, at a height convenient for the patient. To one end of this bar a suitable weight is suspended and a handle is attached to the other end of the lever. The patient can stand in different positions for this exercise, which is also useful for taking the stiffness out of an elbow.

Photographic Action of X-Rays

At the annual meeting of the Röntgen Society, Mr. N. E. Luboshey made a communication on the "Photographic Action of X-Rays." In ordinary photography, he pointed out, the image was confined to the surface of the film; in X-ray work it was embedded in the whole thickness of the film, which was very rich in silver salt, and one image was really piled upon the other. Thus one did not obtain all the detail that was really in the image, and the plate manufacturers were doubtful as to the instructions to give. It was bad practice to look whether the image had been formed, because nothing could be seen unless the conditions allowed fogging, and bad also to develop horizontally with strong reagents. He had developed 10 plates which he had received from Dr. Russ, one of the honorary secretaries, all simultaneously and for the same period of 22 minutes, in a vertical tank into which he inserted the plates vertically through the slots in the inner cover; the tank was air and light tight, but was inverted several times during the development. He had diluted the developer which, in ordinary practice, would have been used only for 5 minutes, with six times its bulk of water. The plates had been exposed for 2, 4, 6, 8, 10 . . . 45, 60 seconds respectively to the rays of a new Coolidge tube; what would be normal exposure with this tube was not known, but some plates would be considered under-exposed, some over-exposed; Mr. Luboshey had not been informed of the conditions of exposure. All the plates (photographs of a hip joint) were pronounced by members to be very good, except those of exposures of 2 seconds and 4 seconds; looking through these two held together, however, Mr. Luboshey observed all the details as on the 15-second plate, and the detail was evidently present in all the plates, no matter how long the exposures. The use of strong developers and of bromide retarders really accounted for much that was ascribed to "secondary radiations," the merits of the vertical (versus horizontal) tank and of strong developers are, of course, controversial points. Mr. Luboshey also showed tintometers built up of strips of various materials superposed in steps; optical glass, he found, made good tintometers; 2 mm. of lead glass absorbed as much as 1½ inches of aluminum foil.



Gymnasium for relieving stiffness of fingers and shoulders. In the foreground men are practicing stretching their fingers and expanding the hand. In the rear they are limbering stiff shoulder joints by working their hands along inclined bars.



Treating the hands and fingers. Spools 2½ inches in diameter and 8 long turn a rod supported in the frame. A lead weight suspended from each spool by a wire is wound up by turning the spool by the grip of the fingers.

Cotton Seed Products and the Chemical Industries

By Erwin R. Thompson

CHEMICAL industries are more often than not dependent for raw materials upon other industries not classed as strictly "chemical." Conversely, of course, many mechanical industries survive only because of their by-products, which are chemically developed. These mechanical and chemical industries (if one may make so rough a differentiation) are generally interdependent, by-products making the profits for the one and furnishing raw materials for the other.

Milling cotton seed, as conducted in England, consists primarily of a series of mechanical operations turning out crude oil and cake, but generally followed by chemical operations for refining the oil. Often the refining and further treating of the oil is conducted as a separate industry, which may be classed as chemical.

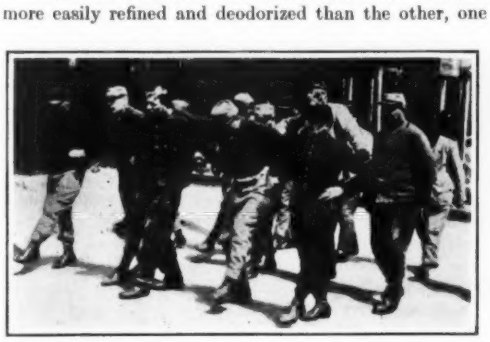
In its usual form, the refining process consists in neutralizing the free fatty acids which always exist to a greater or less degree in crude cotton seed oil. Fundamentally, this refining is a most simple process: merely the agitation of the oil and heating with a solution of caustic soda. Practically, however, there is scope for unlimited exercise of chemical and mechanical knowledge and skill. A simple laboratory test will establish the exact percentage of uncombined fatty acid in a given lot of oil, from which may be calculated the total amount of caustic soda necessary to neutralize it.

Some of the points requiring special skill and experience are the decision upon the strength of solution to be used in a given case; the proper application of the solution to the large tank of oil to ensure intimate contact for the proper period of time and under proper temperatures at various stages of the process; correct sedimentation and separation to avoid loss of refined oil in the foots. The skilful refiner will use just enough alkali to be sure of perfect neutralization and to bring about the proper color of the refined oil. Careless work or improper mechanical equipment tend to the use of too much alkali, making an excessive refining loss, and imparting an alkaline flavor to the refined oil.

Assuming that a good grade of neutral oil has been produced having a proper merchantable color, there is still much left to be desired in the matter of flavor, and if the oil is for edible purposes—its natural market—some process of deodorizing must follow. As now conducted, this process consists essentially in blowing superheated steam through the oil and then rapidly cooling it. Several variations in method are employed, the general object apparently being to volatilize and carry away the small amounts of the comparatively little known substances which impart characteristic odor and flavor. There is room for great improvement both in method and result; for while many of the best deodorized oils are, at ordinary temperature, bland and tasteless, when used pure or in compounds for frying, the best of them often give off disagreeable odors.

Apparatus designed to direct the walk of those who have become club-footed, which forces the patient to move his feet in the proper direction. It is a board with raised ledges at each side to guide the foot.

As the crude oil made from decorticated seed is much more easily refined and deodorized than the other, one step in the direction of making better edible oil might be to change present methods in the crude mill itself, and crush only the kernels (as is done in the United States) instead of the whole seed.



Wounded soldiers practicing body movements. This training is particularly for those who have been wounded in the hips.

Oils intended for ingredients of artificial (compound) lard, are bleached, generally with fuller's earth, and sometimes hardened by the now well-known hydrogen process. Formerly artificial lard was made by the admixture of bleached liquid cotton-seed oil with oleo stock or refined tallow in the right proportion to give a consistency as nearly like lard as possible. But since the introduction of the hardening process, much of the artificial lard is made by mixing with hardened cotton-seed oil.

Margarine, or artificial butter, is in general compounded from the same kind of fats as used for artificial lard. Natural hard fats are more difficult to obtain and higher in price than liquid, so the artificially hardened fats have become immensely popular for all these mixtures, even whale oil having been so used during the war.

Ordinarily, soaps can profitably be made only from such fats as cannot be made marketable for edible purposes; today the Food Controller has severely rationed the soap trade and only allows the use by it of oils which cannot possibly be made edible.

One of the unsolved problems is to make properly edible the oil now expressed from Indian woolly seed. War requirements for fibre to make explosives have caused changes in American milling, looking toward a more intensive recovery of the short lint on the seed. When important quantities of Indian or other woolly seed are again worked in England, no doubt these seeds will be completely defibrated instead of being crushed whole along with the fibres, as heretofore.

After the war the acquired habits of conservation will probably persist; and notwithstanding the cessation of demanding for short fibre for explosive purposes this by-product will continue to be made for other uses, such as artificial silk and leather, and cellulose acetate and the numerous other derivatives.

To summarize, the chemistry of the production and utilization of vegetable oils is susceptible of expansion in several interesting and profitable directions:

(1) Extracting oil by solvent processes, which will make greater yields and yet not extract deleterious substances along with the oil, and which will not be subject to great fire risk.

(2) Treating the residue (cake) to free it from all traces of the solvent, to make it a proper cattle feed.

(3) Refining oils by methods causing least possible loss, and producing the highest grades of edible oils, tasteless and odorless, both liquid and solid.

(4) Utilizing the by-products of refining to the best advantage to recover the fatty acids free from objectionable color and from foreign matter; and the further transformation of the finished products into the finest soaps and other useful merchandise.

(5) Making cotton-seed flour and bread therefrom that will be an acceptable and merchantable product.

(6) Treatment of recovered fibre to make an infinite variety of profitable merchandise.—*Jour. Soc. Chem. Ind.*

A Souvenir of James Watt

AN interesting souvenir of James Watt, representing at once the cleverness of his hands and the versatility of his inventive genius, was recently sold by auction at Coulter Mains, Lanarkshire, among many other historic and antique objects belonging to the estate of the late Mr. Adam Sim, a noted collector. This was a chamber pipe organ which Watt designed and produced with his own hands in Glasgow in 1762. Built in his own house in Highstreet, it eventually came into the hands of a Mr. John Steven, who, about the beginning of last century, was the only music seller in the city. In 1807 it was bought by the minister of St. Andrew's Church, and after being used one Sunday in that sacred edifice its further use was interdicted by the Presbytery, and caused much excited comment throughout Glasgow. The organ lay for years in the church unused, and was ultimately sold through Steven to Bailie Archibald McLellan for £400, on whose death it became the property of Mr. Sim, of Coulter Mains, who paid for it £50. At the recent sale it was knocked down to a Mr. Black for £400, who, it was afterward discovered, was acting for a son of one of the town councillors of Glasgow—ex-Deacon Convener Macfarlane—who is giving it to the Glasgow Corporation for fitting preservation.—*The Engineer.*

An apparatus used for finger movements. It is a keyboard, the keys of which have springs of varying strength, thus providing a varying resistance to the action of the fingers of the patient.

The Gelation of the Natural Emulsoids*

A Subject Which Has Long Been a Matter of Controversy

By S. C. Bradford, B.Sc., The Science Museum, South Kensington, London

The question of the structure of gels has long been a matter of controversy. Perhaps the theory which has found the most favor is that which considers them as systems of two liquid phases persisting from the sol stage. However, Hatschek [1916] has shown, from the stress-elongation curve, that this theory is untenable. Since it is now recognized that the distinction between the suspenoids and emulsoids is rather a question of the affinity between the two phases than of the solid or liquid state of the disperse phase, there seems to be the less reason for refusing, as he indeed predicted, to extend v. Weimarn's theory to the natural emulsoids and regard their gelation as a crystallization process.

As early as 1835 M. L. Frankenheim suggested that these bodies were aggregates of small crystals, and attributed their density and easy solubility to the existence of pores. In 1879 it was proposed by K. v. Nageli that gels consisted of molecular complexes, with crystalline properties, separated by skins of water and forming meshes in which the water was contained by molecular attraction. Since that time a number of unsuccessful attempts have been made to devise a geometrical structure which would account for the properties of gels. Any mathematical theory must, however, be consistent with the considerations that (1) the elasticity of gels varies considerably, some being practically inelastic, and (2) that, if the structure is due to the action of the directive forces of crystallization, it would be likely to vary according to the nature of the gel. The latter principle finds confirmation from the work of Zsigmondy and Bachmann [1912] on the crystallization (gelation) of sodium and potassium oleate, palmetae and stearate solutions. These considerations lead to the view that a single network may not account for the elastic properties of different gels.

As was pointed out by Hatschek [1914] the lens-shaped form of gas-bubbles occurring in gels must have some relation to their structure. He found that the bubbles place themselves at right angles to pressure applied to the gel and parallel to tension. By measuring the angles between pairs of bubbles in 10 per cent gelatin Hatschek found certain values approximately repeated a number of times, although other measurements varied enormously, so that whether the angles have much to do with the crystalline structure is doubtful. However, planes of cleavage are suggested and the simplest structure that would conform approximately to the conditions is that of piled shot or a brick-stack. In this relation it is remarkable that ultra-microscopic examination of gelatin gels of from 1 to 6 per cent, from which the liquid has been expressed, shows flocks of separate grains of irregular shape with clear spaces separating the flocks. Increasing concentration reduces the size of the grains, as would be required by v. Weimarn's theory, and, at the same time, the empty spaces gradually disappear, until, at about 6 per cent the solid phase fills the whole field and the single grains can no longer be differentiated. Agar and silicic acid show a similar globulitic structure. [Bachmann, 1911; Zsigmondy and Bachmann, 1912.]

During experiments on banded precipitates in gels the slow motion of solid particles through gels was frequently observed. Moreover, many precipitates appeared gradually to settle down, leaving the gel apparently unchanged above. This suggests rather that the individual gel particles are more easily separated than those fast in a network.

It may be noted in this connection that the solid particles deposited by the chemical reaction of solutions diffusing into gels are frequently spherical in shape, resembling natural spherulites. Their form may be attributed to the adsorption, by the granules, of the reaction components from the diffusing solutions so that the value of v. Weimarn's $\frac{P}{L}$ at the surface of the granules is greater than in the surrounding gel, and, owing to the diffusion of further supplies of nutrient matter, becomes larger than the original number of condensation centers. The grains are therefore unable to grow as regular crystals and develop as tarlike growth figures, globular aggregates, or as sphericla crystals [Bradford, 1917]. It is evident that the slower the velocity of crystallization of a particle the more easily will the value of $\frac{P}{L}$ increase in this way. Now in the case of large unwieldly molecules, like those of the natural emulsoids, the directive force of crystallization may very well be small, and for this reason, coupled with the inertia of the molecules and the viscosity of the medium fresh molecules might take a considerable time to fit themselves into the crystal structure. Consequently molecules or aggregates might arrive faster than needed for the regular growth of crystal faces and result in the production of globular crystals, or even in extreme cases of aggregates piled up without regard to orientation. Perrin's large-grained emulsions of mastic and gamboge exhibit this spherical shape clearly, and Moore observed chains of globules in dilute silicic acid [1915].

On the basis of such a formation it is perhaps a little difficult to understand the coherence of gels and to explain exactly their stress-elongation curves. The coherence is to some extent affected by the films which form on the surface during setting. And there may be amicroscopic filaments which come into play. The existence of an elastic surface layer around the disperse particles might also contribute to the effect. It will also be remembered that the liquid expressed from a 5 per cent gelatin gel contains from 0.16 to 0.46 per cent gelatin [O. Bütschli, 1896], while that from a 2.23 per cent agar gel varies from 0.09 per cent at 5° to 0.47 per cent at 36° [Hardy, 1900]. The viscosity of this liquid would be appreciably greater than that of water.

The above figures show that the concentration of the liquid in equilibrium with the solid phase varies with the temperature. And, since at a few degrees higher temperature, the whole mass was fluid it is difficult to resist the conclusion that the excess has a crystallized cut on cooling. This is in accordance with the influence of concentration on the temperature of gelation [Rona, 1902; Rohloff, 1907; Levites, 1908].

A similar inference may be made from another piont of view. P. P. v. Weimarn's researches show how to prepare a given substance in any desired degree of dispersity, and indicate that the disperse particles are crystalline however great the specific surface. From his formula, $N=K\frac{P}{L}$, a sol or a gel results according as a large number, N, of crystallization centres are produced from a large excess concentration, $(P=C-L)$, or a small solubility L. Intermediate values of P and L give rise to micro or macro crystals. If his formula applies to substances for which this intermediate stage vanishes, by reason of their slow velocity of crystallization, the transition point between the sol and gel stages should correspond to the act of crystallization. From the general behavior of sols, increase of concentration beyond a limiting value does lead to precipitation. Since, in the case of the lyophile sols, there is considerable affinity between the two phases, a temperature variation is indicated, as is confirmed by Hardy's figures for the liquid expressed from agar. And the transition or gelation point should in general be a function of the concentration and temperature of the sol. The influence of concentration is well exemplified by mastic. Dilute alcoholic solutions of mastic poured into water produce sols, while a greater concentration of mastic gives fairly permanent gels. Whether or not the precipitate forms a coherent gel or merely sinks to the base of the vessel would depend on its mass and degree of dispersity. If the precipitate is sufficiently voluminous it would drink up the liquid and form a coherent gel.

The gels of camphorylphenylthiosemicarbazide investigated by Hatschek [1912] led him to suspect a crystalline structure formed by growth of amicrons into a network: a conclusion which he hesitated to accept on account of the mathematical difficulties. These gels appear to be typically elastic, and are produced (1) when an up to about 5 per cent hot alcoholic solution of the substance is suddenly cooled, (2) from the gradual or rapid cooling of toluene solutions of similar concentration, or (3) by pouring a concentrated alcoholic solution into petroleum. The latter method gives gels with a concentration as small as 1:400. The solubilities in alcohol, toluene and petroleum are respectively 0.5 per cent, 1 per cent, and very small. P. P. v. Weirmarn's theory easily supplies an explanation of the first and third cases, though the second is more difficult to understand, for the slow cooling of an alcoholic solution leads to the production of macrocrystals, though the substance is less soluble in alcohol than in toluene. The explanation may lie in a larger value of the factor K in v. Weirmarn's formula, or a slower velocity of crystallization from toluene solution.

Considering the general case of a substance of very high molecular weight and low diffusivity. Let this be treated with a liquid such that the solubility, L shall neither be too great in the cold, nor increase too rapidly on heating. Then, on applying heat, the process will be reversible and the Noyes-Nernst formula for the velocity of solution, $V=\frac{D}{\delta}S(L-C)$ will hold. Since L is not very large and D is very small, the velocity of solution will also be very small and the sol stage will persist. Further heating will lead in time to the breaking up of the aggregated particles of the sol and an approach to true solution. If the stage of single molecules is reached this may be regarded as a true solution, though the diffusion constant will be that of a sol. Notwithstanding the considerable size of the molecules the system may be considered homogeneous and v. Weimarn's formula applied. On cooling, with reduction of L, aggregation will commence, but the velocity of crystallization, $V=\frac{D}{\delta}S(C-L)$, will be a minimum so that the diminution in L will gradually give a larger and larger P and a still greater value of $\frac{P}{L}$. Actually $\frac{dN}{dL}=-K\frac{C}{L_2}$. The velocity of crystallization will also increase. And if, when spontaneous crystallization takes place, N has become sufficiently large, a gel will be formed. Gelation will therefore be dependent on the concentration, solubility, and the factor K, which represents the degree of association and viscosity of the sol. Consequently such a sol, of which the association had been diminished by long heating, would be less likely to gelate on cooling than one which had been freshly solated.

If would be somewhat remarkable if such substances should not occur, and the reversible emulsoids appear to fulfil these conditions completely. They form sols of considerable concentration, viscosity and aggregation, and have very low diffusion constants, although little is known about their true solubilities. Heating at constant temperature decreases their viscosity while cooling increases it—changes which are now seen to be in complete accordance with Einstein's formula. Osmotic pressure varies in the opposite sense. They are generally not very stable bodies, but the behavior of gelatin is particularly remarkable. By continued heating at 100° the submicrons grow smaller and fewer, until, after thirty-six hours [Levites, 1908] only amicrons are present and the viscosity has changed from 2.29 to 1.39 and become constant. The sol now refuses to gelate and is known as β-gelatin. This is very soluble but, on evaporating nearly to dryness and cooling, it passes through a gel stage which by drying forms a mass resembling sheet gelatin.

The heat coagulation of albumin must be supposed to be due to the chemical production of an insoluble compound. In this case gelation is irreversible.

If it be conceded that the solubility of silicic acid depends on the hydration and aggregation of the molecule its gelation follows at once from v. Weimarn's theory. The gel is formed immediately (in the same way as that of aluminium hydroxide, for example), when a moderately concentrated solution of sodium silicate is neutralized with mineral acid. This is due to the sudden production of a highly aggregated insoluble form of silicic acid, owing to the concentration, viscosity and aggregation of the reaction medium. On the contrary, when the silicate is slowly stirred into the acid medium, which has the ordinary properties of a liquid, probably a true solution of silicic acid is formed at first. This is indicated by its high diffusivity. Changes then take place, possibly in the hydration of the molecule, which reduce the solubility and cause gradual aggregation with increase of viscosity [Garrett, 1903] and sol formation.

If it is preferred to regard the immediate precipitation of silicic acid as due to electrolytes, its gelation is no less in conformity with v. Weimarn's theory.

Returning to the reversible sol-gel transformation, it has been seen that the low diffusion constant of the natural emulsoids, by retarding crystallization, allows the accumulation of a sufficiently large excess concentration which, together with their large value of K, will cause gelation on cooling. This low diffusion is also responsible for the permanency of the fels and hysteresis of sols, since it prevents the subsequent development of larger crystals in gels and retards changes in the aggregation of sol particles.

If one regards the precipitated particles as consisting of aggregates of amicroscopic crystals or filaments, the specific surface would be so great that the volume of the compressed surface layer of absorbed liquid would be considerable and would explain the contraction of the total volume of liquid and gel and the evolution of heat

*From *Science Progress*.

during imbibition. The amicrons may also be regarded as surrounded by a liquid envelope due to the molecular cohesion between the liquid and solid phases. From this point of view the phenomena exhibited by gels should be influenced by the lyotrope series of dissolved salts which affect the surface tension and the affinity of the liquid and solid phases. The connection between adsorption of solvent and imbibition, and the similar effect of the Hofmann series on both, was pointed out by Lillie [1907].

If osmotic pressure is due, as Lillie suggests, to adsorption of solvent by the dissolved particles, the osmotic pressure of emulsoid sols should be decreased by salts in the order $CNS < I \ldots < SO_4$ as was found to be the case. The diminished pressure should hardly be caused by aggregation of the sol particles, since the predipitating effect of the cations has not commenced at the concentrations employed, although anions hinder the precipitation in the opposite order [Pauli, 1913]. Hatschek found the same series for the clearing of oil emulsions. The temperature of gelation should, however, be diminished in the order $CNS > I \ldots > SO_4$ as was found by Levites [1908]. The change in viscosity with time [Schroder, 1903] follows in the same way as due to a diminution in the precipitating forces. If the velocity of crystallization is reduced, aggregation will be hindered and precipitation will not take place until a lower temperature. Dialysis will leave a sol containing smaller particles, the effect being similar to that of prolonged heating. Similarly the elasticity of gels is increased by salts which favor imbibition and *vice versa*. And the double refraction of deformed sols shows the same lyotrope effect [Lieck, 1904].

From these considerations the application of v. Weimarn's theory to the gelation of the natural emulsoids appears to account for most of the properties of gels, including their remarkable hystereis so suggestive of their connection with vital phenomena, nor is the theory necessarily inconsistent with their elasticity and the thermal anomaly of stretched gels, though, from analogy with rubber, the latter property at least would seem to be connected with the solid phase, since this hydrocarbon exhibits these phenomena in the solid state which may correspond to that of a dried gel.

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Pitch as a Fuel

Pitch is composed chiefly of free carbon, and of hydrocarbons which become volatile on heating above 400 deg. C. Under correct conditions it can be burned completely to carbon dioxide and water vapor. The elementary analysis of pitch shows it to contain from 90 to 94 per cent of carbon and from 4 to 4½ per cent of hydrogen. The "approximate" analysis, however, gives a better indication of its composition and of the difficulties that may be expected when burning it upon a commercial scale, for when it is raised to a red heat in a platinum crucible two-thirds of it passes off as volatile matter, and only one-third remains behind in the crucible in the form of pitch-coke. When tested in the bomb type of calorimeter pitch shows a calorific value of 15,600 B. Th. U. gross or 15,000 B.Th.U. net; that is, it possesses a heat value equal to that of the best Welsh steam coal. If supplied with sufficient oxygen and raised to a temperature sufficiently high to secure complete combustion it is therefore a valuable fuel, and the problem of its efficient utilization under steam boilers resolves itself into one of providing the necessary conditions inside the boiler furnace.

Two difficulties are met with when burning pitch under industrial conditions in ordinary grates and furnaces, both due to certain physical characteristics of the fuel. In the first place it softens at a comparatively low temperature, and passes into the semi-fluid state by almost imperceptible stages. In the second, the hydrocarbon gases which form two-thirds of the weight of the fuel when heated come off with great rapidity when once the molten pitch has attained the temperature necessary for gasification. At a moment, therefore, when a great increase in the air supply is necessary, the molten pitch is flowing into the air spaces between the firebars of the furnace, and is closing these, with disastrous results for the proper combustion of the evolved gases.

The earliest attempts to burn pitch at a tarworks in the North were made by simply breaking up the pitch and charging it into the furnace of a hand-fired Lancashire boiler, mixed with coke-breeze in the proportion of 45 per cent of crushed pitch to 55 per cent of breeze, the idea being that this would yield a firing-mixture similar to an ordinary bituminous coal. The steam-raising value of this mixture was good, but it produced much smoke, and also an oily deposit of soot on the economizer-tubes which could not be removed by the scrapers and had eventually to be "burnt-off," a troublesome and expensive business. By altering the relative proportions of pitch and breeze, however, and by adding a small quantity of ordinary coal, the smoke trouble has been overcome, and this firm is now burning a mixture of 75 per cent of breeze, 18 per cent of pitch, and 7 per cent of coal in the furnace of a hand-fired Lancashire boiler with quite satisfactory results.

As regards trials of pitch for steam-raising purposes carried out in London, the fuel expert of the London Coke Committee, Mr. E. W. L. Nicol, soon after the outbreak of war began to experiment with this use of pitch, since it was seen that if a mixture of coke and pitch could be burned with a fair measure of efficiency under boilers, a better market would be created for these two by-products of the gas-making and tar-distilling industries, and incidentally the demand for ordinary coal would be reduced. A special type of firebar was designed by Mr. Nicol for the purpose, its chief feature being that it contained a channelled passage leading to a spoon-shaped trough, in which the molten pitch collected and remained while the volatile gases were distilled. Steam-jets were employed with this bar in order to supply the heated air necessary to mix with and consume the large volumes of hydrocarbon gas produced as the solid pitch fed on the flat and cooler end of the bar melted and flowed down into the cavity at the center, where the heat of the surrounding incandescent fuel gasified it. These "pitch-bars" could be sandwiched, in any number required, between the ordinary bars of the the furnace grate, the latter being removed to make place for them. The pitch coke that collected in the center trough of the bars, after the gases were distilled, was cleared out, from time to time, and burned at the rear end of the furnace on ordinary firebars. The trials of these special "pitch-bars" were suspended in 1917 owing to the increase in the price of pitch in London, but so far as they went they proved that pitch can be burned with coke in this way without excessive nuisance from smoke.

Although creosote and coal-tar have been used successfully as liquid fuels with the ordinary forms of fuel-atomizer, pitch hitherto has not been employed in this way. It is evident however that could pitch be rendered as fluid as tar, by the application of heat or by other means, the method of spraying it into the furnace with compressed and preheated air would solve the problem of burning it without the production of smoke and with high efficiency. A brief account may therefore be given of some of the recent patents for increasing the fluidity of pitch and other liquid fuels, and also of some new forms of atomizer, in which a preheating coil is provided as an integral part of the apparatus.

The patent of Phillips (No. 14778 of 1913) covers a method of reducing the viscosity of certain thick oils by the addition of 8 per cent of naphthalene. Since naphthalene is a product of tar distillation it would appear that it would be simpler, and also have the same effect, if the distillation of the tar were carried only far enough to distil what are known as the light oils, and if the naphthalene and heavy oils were left in the pitch, when this was designed for use as a fuel. The following are the temperatures according to Martin at which the various components of coal tar distil: Below 170 deg. C., light oils; 170 to 230 deg. C., middle or carbolic oils; 230 to 270 deg. C., heavy or creosote oils; 270 to 400 deg. C., anthracene oils. The bulk of the naphthalene passes over with the middle or carbolic oils, and to stop the distillation of the tar at this point would therefore mean the sacrifice of the larger portion of the distillate. The question of the demand for and relative prices of the various products of the distillation of course enters into the problem here, and it might prove the more economical course at one period to recover and sell all the possible products of the tar, and treat the pitch as waste material, and at another to stop the distillation at 200 deg. C. and recover and sell only the benzole and toluene, when a "soft" pitch, capable of use as a liquid fuel, would be left in the still.

Patent No. 110023 of 1916, granted to G. Heyl, covers a method of producing a liquid fuel from pitch suitable for spraying, by dissolving 50 per cent by weight of this material in heavy creosote oils, after they have been purified from sulphur compounds and acids by treatment with caustic soda. This plan allows the anthracene oils to be recovered from the tar before the pitch is used as fuel, but here again it would appear to be a waste of heat and energy first to separate the heavy creosote oils from the pitch and then to recombine them in order to produce a liquid fuel, unless the value of the recovered anthracene was fairly high.

As already stated, the economic advantage or disadvantage of the application of these methods of rendering pitch available as a liquid fuel turns upon the demand for, and relative selling prices of, the various distillation products of tar, and of the liquid fuel produced, and what proves to be the wiser plan in one district may be quite otherwise in another, even at the same period of time.

Among new forms of "atomizer" for very thick and viscous liquid fuels, patent No. 101444 of 1916, granted to H. Bolling, of Christiania, describes a method of melting the pitch by aid of superheated steam, while German patent 300301 of 1916, granted to H. Sieger, describes a more complicated form of gas-heated vaporizer for liquid fuels, in which the principle of flameless combustion is employed to gasify the fuel before it is injected into the combustion chamber of the furnace or boiler. Another German patent, No. 299864 of 1915, makes use of an electric resistance coil for pre-heating and of a pilot-jet of light-oil for ignition purposes. All these devices, of course with some modification, might be applied to the atomization of pitch.—From the Engineering Supplement of the *London Times*.

The Photographic Spectra of Aerolites

Distinguishing the meteorites, the cosmic wanderers which are drawn down upon our earth, as siderites when they consist essentially of iron and nickel, and as aerolites when they are essentially silicates of the olivine type interspersed with nickliferrous iron, Sir William Crookes recently submitted some aerolites to spectroscopic examination. The paper, which he presented to the Royal Society deals only with the spectroscopic analysis of 30 aerolites, mostly samples of 2 or 3 grammes weight obtained from the Natural History Museum. General analyses of these aerolites are not given. For the spectroscopical tests, use was made of a spectrograph which Sir William reconstructed at least six times. Sir William photographed the spectra of the aerolites and compared these photographs as to line intensity and position with the photographs of the spectra of similar compounds and specially prepared mixtures. For this purpose he needed a slit of constant width for experimenting on different days; his usual slit width being only 0.008 mm., he found considerable difficulty both with the slit material and the mounting. Schumann, in studying his rays in the ultra-violet, had used jaws of hardened steel; Crookes wished to study the whole spectrum, and his chemical laboratory was inconveniently near his physical laboratory for making use of iron jaws. Having tried rolled, non-corrosive cobalt, he finally adopted quartz jaws; but the sharp edges of 45 degrees splintered too easily, until he put a very narrow bevel on the front of the quartz plate, so that the sharp edge formed an angle of 90 degrees. To prevent stray light from passing through the plate, he covered the quartz with gold, by kathode deposition up to the edge. In order to secure constancy of the slit width, he mounted three jaws, of widths 0.008, 0.025, 0.06 mm. on blocks of pairs of "fixed slits" of brass. As regards the gases in the meteorites, about which there is considerable controversy, Sir William merely describes the arrangement he made to convince himself of the absence of inert gases, notably of helium; he absorbed the gases escaping from the aerolites at red glow, after Soddy, by heating them with metallic calcium, which would bind all but the inert (rare) gases. The spectroscopic examination shows that only eleven elements occurred in the aerolites; iron, chromium, nickel, magnesium, silicon, sodium, manganese, and also potassium, aluminum, calcium. The first four were alone present in quantity and, with three exceptions always in the nearly same proportions. That, Sir William writes, seems to suggest that the different aerolites had a common origin in the disruption of some stellar body which had completed its cosmical evolution, in other words, that the aerolites were fragments of a finished cooled planet. The siderites would have a different origin, or might have formed the solid core from which the chromium and other elements would have been separated, leaing the magnetic elements iron and nickel as a residue in the familiar meteorites. So far as we are aware, the aerolites generally found are supposed to differ from terrestrial rocks, resembling the periodotites most, aqueous silicates of magnesium, calcium, iron and aluminium, which are characterized by the presence of small percentages of chromium and nickel.—*Engineering.*

The "Grain" of Wood*

With Reference to Direction of Fibre

By Arthur Koehler, Specialist in Wood Identification, Forest Products Laboratory, Madison, Wisconsin

UPON the direction of the grain in woods used in airplane construction may depend the strength of the machine and the safety of the pilot. It is, therefore, of great importance that the inspector be familiar with the different kinds of "grain" and be able to determine the direction and slope of the fibers, so that he may eliminate pieces which, on account of their cross-grain, would be likely to reduce seriously the margin of safety.

There are various kinds of "grain" in wood, and various uses of the word. The annual rings are often considered as constituting the grain. Woods with wide and conspicuous rings are said to be "coarse grained," and those with narrow rings, "fine grained." If each annual ring is composed of a hard and a soft layer, as for example, in the yellow pines, Douglas fir, oak, and ash, the wood is said to have an "uneven grain," as contrasted with the "even grain" of white pine, basswood, maple, and mahogany. Occasionally "uneven grain" is used with reference to woods in which the annual rings are very irregular in width. Cypress is often of this nature.

When lumber is sawed along the radius of the annual rings, it is said to show "edge grain," that is, the "edge" of the annual ring shows on the face. This is also known as "comb grain" and "vertical grain." When lumber is cut parallel or tangent to the annual rings, it is said to show "flat grain." In grading rules a slope of 45 degrees for the annual rings is considered the line of demarcation between edge grain and vertical grain. The cross-section of timber is usually called the "end grain."

For woods in which the annual rings are inconspicuous as in maple, red gum, and mahogany, the word "grain" is rarely used with reference to the annual rings. Thus the expression "coarse-grained maple," "uneven grained red gum," or "edge-grained mahogany" is seldom used.

The word "grain" is also used with reference to the size of the pores; woods with comparatively large pores, such as oak, chestnut, ash, and African mahogany, are said to have a "coarse grain," while those with small pores, such as maple, cherry, basswood, and red gum are called "fine-grained." Painters designate them as "open" and "close grained" respectively, the former requiring a filler. Occasionally the word "texture" is used in place of "grain" in describing the width or uniformity of the rings or the size of the pores.

Since the term "grain" is used in describing a number of different characteristics of wood, it would help considerably to avoid confusion if the width of the rings were expressed by the terms "wide-ringed," "narrow-ringed," or "with rings of medium width"; the uniformity or irregularity in the structure or width of the rings, by "even texture" or "uneven texture; and the size of the pores, by "coarse texture," or "fine texture." The terms "edge grain" and "flat grain" are more definitely fixed in their meaning and should be retained.

A common use of the term "grain" is to describe the direction in which the fibres extend in a tree or piece of lumber.

"Straight grain" means that the fibres run practically parallel with the main axis of a tree, or are parallel with the main axis of any given piece.

"Spiral grain" means that the fibers extend in an oblique direction circumferentially in the tree, so that if extended they would wind around the tree trunk, forming a spiral (see Fig. 1). Wood which has a spiral grain, when split radially, produces a twisted surface.

"Interlocked grain," also called "cross grain," is caused by alternating layers of wood being spirally grained in reverse directions; that is, the fibers put on for a number of years may slope in a right-handed direction, and then for a number of years the slope reverses to a left-handed direction, and later changes back to a right-handed pitch, and so on (see Fig. 2). Such wood is exceedingly difficult to split radially, although tangentially it splits fairly easily. Interlocked grain is common in black gum, red gum, some cotton-wood, eucalyptus, and many tropical trees.

Diagonal grain is the slanting of the wood fibres brought about by causes other than spiral grain in the tree. Usually it is due to sawing straight grained timber in a direction not parallel with the fibers, a procedure to be avoided, if possible, in cutting stock in which strength is an essential feature. Curvature in the tree trunk and other irregularities in the grain outside of local wavy and curly grain may, however, make it impossible to avoid the production of diagonal grain in cutting up certain logs. The common method of cutting lumber is to saw parallel with the central axis, which produces more or less serious diagonal grain in the lumber, depending on the taper of the log (see Fig. 3). Obviously, diagonal grain weakens the lumber, and several mills cutting airplane stock are now cutting parallel to the outer surface of the log. Diagonal grain may also be produced by cutting up quarter-sawed lumber and not getting the faces parallel to the annual layers of growth (see Fig. 4), or by cutting up plain sawed lumber and not getting the faces parallel to the direction of the fibers (see Fig. 5). Diagonal grain produced in the latter way is difficult to distinguish from natural spiral grain in the tree. However, since so far as is known, they are equally weakening, there usually is no need to distinguish between the two.

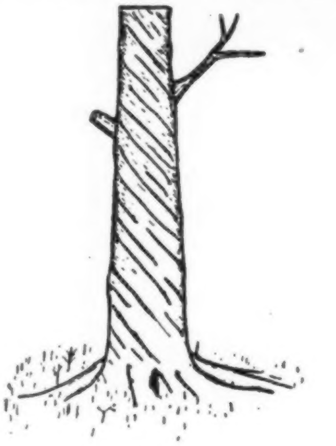

Fig. 1

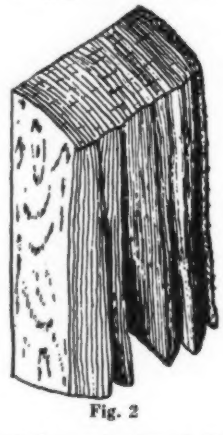

Fig. 2

Both spiral grain and diagonal grain are also called "cross grain." Natural spiral grain can be detected by the twisted surface produced in splitting long pieces, and, according to Oakleaf,[1] usually by the fact that the parabolas and elipses produced by the intersection of the annual rings with the flat surface, do not extend in the same direction as the fibers.

HOW TO DETERMINE THE PRESENCE AND SLOPE OF SPIRAL GRAIN ON THE TANGENTIAL FACES

Spiral grain can be detected most easily by splitting wood in a radial direction. This, of course, mutilates the piece and is not always permissible. The direction of seasoning checks on the tangential surface also indicates the direction of the fibers. If no checks are present the direction of the resin ducts (brownish hair-like lines), which are found only in pines, spruces, Douglas fir, and larch or tamarack, serves as a guide for determining the slope of the grain. In the hardwoods, especially in species in which the pores are distinct, such as ash, oak, hickory, walnut, mahogany, and birch, the direction of the pores indicates the direction of the grain. Coniferous woods seem to be more subject to spiral grain than hardwoods. If the resin ducts are absent or obscure, or if the pores in hardwoods are obscure, the direction in which the ink spreads will indicate the direction of the grain. This test can best be applied by using a fine pointed pen and an alcohol solution (about ¾ alcohol and ¼ water) of some dye-like safranin. If the pen, dipped in the dye, is pressed slightly into the wood, the dye will spread from about ⅛ to ¼ of an inch along the fibres. The direction of the grain can be followed up by again placing the point at the extreme to which the ink has spread along the fibres, and so on until a line sufficiently long to determine the slope of the grain has been made.

Some determine the direction of the grain by picking up the fibers with a knife and observing in which direction they tear out. The presense, but hardly the slope, of spiral grain may also be determined by the dip of the fibers where chips are torn out of the radial surface by the planer. With a hand lens magnifying about 15 diameters the direction of the fibers can be seen plainly. In no case should the direction of the annual rings of the tangential face be taken as the direction of the grain.

The slope of the grain on the tangential face is usually expressed as the number of units (inches or other units) along the length of the stick in which the grain deviates one unit from a radial plane parallel to the main axis of the stick. This is expressed as 1 in 12, 1 in 30, etc.

HOW TO DETERMINE THE PRESENCE AND SLOPE OF DIAGONAL GRAIN ON THE RADIAL OR TANGENTIAL FACE

Diagonal grain on the radial surface can usually be detected by the direction of the annual rings. The slope of the grain on the radial face is expressed as the number of units along the length of the stick in which the grain (annual rings) deviates one unit from a tangential plane parallel to the main axis of the stick.

Diagonal grain on the tangential surface and its slope can be determined in the same manner as spiral grain, from which it need not be differentiated.

It must be remembered that if the stick has any taper, the slope of the fibers with respect to its main axis, and not to the surface of the stick, gives the true slope of the grain. This is equally true for spiral grain.

The slope of either spiral or diagonal grain may be more in one portion of the stick than in another; therefore, the entire length of the stick should be examined.

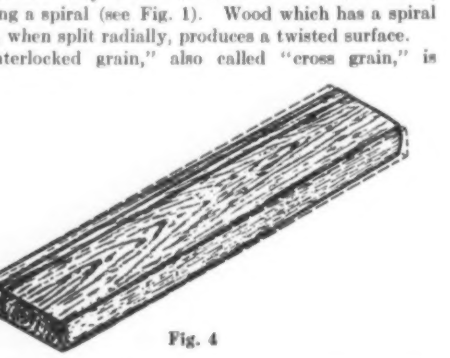

Fig. 4

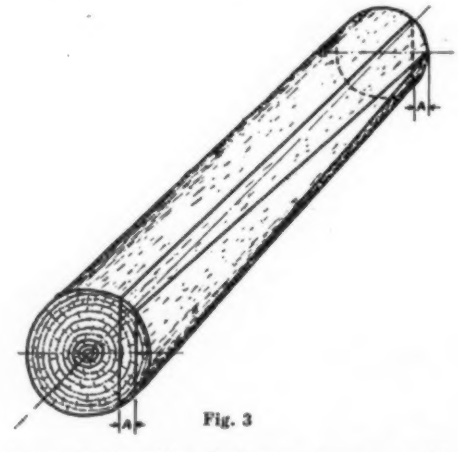

Fig. 3

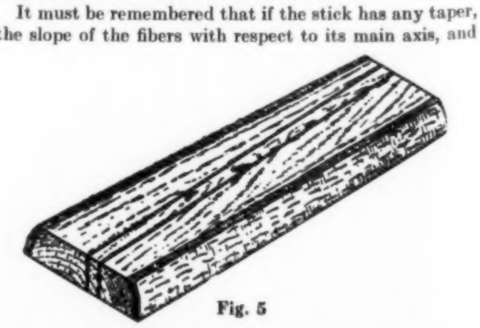

Fig. 5

*From the *West Coast Lumberman*.

[1] Oakleaf, H. B.—"Inspectors' Manual, Equipment Division Signal Corps."

HOW TO DETERMINE THE PRESENCE AND SLOPE OF SPIRAL OR DIAGONAL GRAIN WHEN THE SURFACES ARE NOT TRULY RADIAL OR TANGENTIAL

On shaped sticks which are round or oval in cross-section, surfaces sufficiently tangential or radial to determine the direction and slope of the grain may be found. The direction of the grain in rectangular pieces may be determined as in other pieces in which the faces are truly tangential or radial, that is, by splitting, checks, direction of resin ducts, pores, medullary rays, and annual rings, or by the ink test, depending on whether spiral or diagonal grain is being looked for.

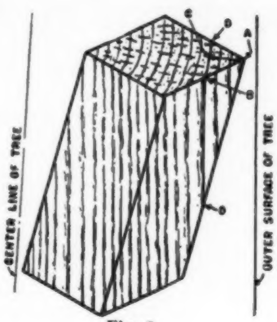

Fig. 6

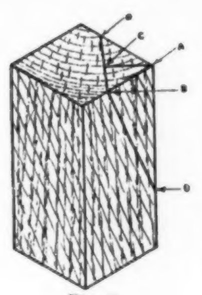
Fig. 7

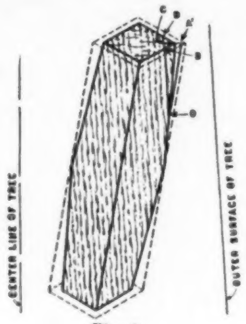

Fig. 8

The slope of the grain in rectangular pieces may be determined as follows:

Diagonal grain—Starting some distance from the end and on the edge farthest from the center of the tree, or on the edge nearest to the center, trace back an annual ring to the end of the stick, as O B in Fig. 6. Follow the ring across the stick, as B C D. Measure the distance from the corner A to the ring B C D. Then (the distance) A C in (the distance) A O is the true slope of the grain.

Spiral grain—Starting some distance from the end of one of the two edges which are neither farthest from nor nearest to the center of the tree, trace back the grain to line B C D and connect A with the nearest point on the line B C D, then (the distance) A C in (the distance) A O is the true slope of the grain at that part of the stick. In some woods, and even in conifers containing resin ducts, it is often exceedingly difficult to find the proper direction for the line O B, so that splitting of a corner may be the only accurate way to find the slope of the grain in a given sample.

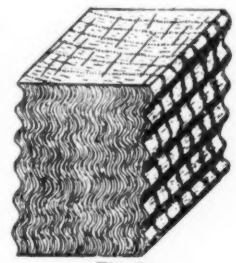
Fig. 9

If both spiral and diagonal grain are present in a stick the direction and slope of each may be determined separately by the methods above.

If the stick has any taper, as is often the case in fuselage struts (the distance) A C in (the distance) A O (Fig. 8) is the true slope of the grain where A O is parallel to the main axis of the stick.

OTHER IRREGULARITIES IN THE DIRECTION OF THE FIBERS

True wavy grain is due to a wavy arrangement of the fibers, producing undulation on a split radial surface. (See Fig. 9.) Wavy grained wood will split straight tangentially but the wavy direction of the fibers can be seen on the tangential surface. Irregular protuberances on the tree trunk may produce one or several "waves" in the annual rings. This is seen best on the radial face. (See Fig. 10.) In this case the waves are not as regular as when the undulations occur on the radial face. A bulge in the annual rings may indicate the presence of a pitch pocket toward the inner side of the tree.

Curly grain is an irregular distortion of the fibers as seen on the tangential surface. (See Fig. 11.) It is produced in the healing over of knots or injuries received by the growing tree. It can be detected by noting carefully the direction of the fibers or the irregular way in which the fibers are chipped out by the planer knives. The ink test is also good for determining the direction of the fibers in curly grain.

KNOTS

Knots are weakening because of the distortion of grain which they produce, although they are denser as a rule than the surrounding wood. Knots start nearly always at the pith and grow in diameter from year to year, so that they are cone shaped, with the apex, at the pith (Fig. 12). Knots from sprouts which come out of the side of the tree trunk do not, of course, originate at the center.

"Live" or "sound" knots are intimately connected with the fiber of the surrounding wood, especially from the lower side, because here the sap brought up from the roots must flow from the sapwood of the trunk to the sapwood of the branch and thence to the leaves. From the upper side the connection is less intimate, and for this reason the cleft in a knotty piece of wood split from the lower side usually runs into the knot, but the cleft in a piece split from above may run around the knot, and the wood is more easily split.

After the limbs have served the tree for some time, the lower ones may become overshadowed by the growing crown to such an extent that they die. After a branch is dead it forms no further connection with the surrounding wood, and often if cut across, as in plain sawed lumber it can be removed. Such a knot is called a "loose knot." If the knot is firmly held in position but is surrounded by bark or pitch, it is termed an "encased knot." A knot cut lengthwise is called a "spike knot," and a knot less than one-half inch in diameter is called a "pin knot."

Dead branches may persist for a number of years but eventually break off. The annual rings of wood which are formed subsequently grow over the stub. At first considerable distortion of grain may be produced when a branch heals over but eventually the grain becomes straight.

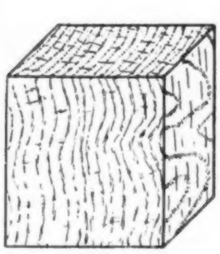
Fig. 10

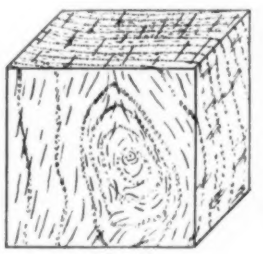
Fig. 11

Notes on the Speed of Fishes, Especially the Alewife

THE question of the speed with which fish swim has elements which, it would seem, might make it popular, but there appear to be few recorded observations. It becomes of economic importance in connection with the effect of water power development on the fisheries.

Three preliminary points should be mentioned. In the first place some fish, besides swimming, are able to jump from the water and by this means pass over a current which it would be wholly impossible for them to swim through; we are not concerned here with that question. Secondly, it is assumed that if a fish can maintain itself against a steady current of so many miles an hour, it can swim the same number of miles an hour in still water. Thirdly, the velocity of a stream is much less at the bottom or behind obstacles than at surface.

A Belgian engineer (G. Denil), while studying fishways, concluded that the salmon could swim at a speed of 3.15 meters a second for at least 14 meters. The author also refers to similar figures given by a French engineer. In a report on the obstructed condition of the Frazer River published in the report of the British Columbia Commissioner of Fisheries for 1913, the author (G. P. Napier) expresses the opinion that the limiting velocity of a steady stream up which a sockeye salmon is apparently capable of swimming a very short distance lies between six and seven miles an hour. Mr. H. von Bayer, of the Bureau of Fisheries, published a paper on fishways in 1910, in which he said that the current velocity in fishways should not exceed 10 feet per second. It is remarkable that the three figures, which appear to be independent of each other, are almost identical. The Belgian estimate is about 6.9 miles an hour, the Canadian's is 6 to 7 miles an hour and the American's is 6.8 miles an hour.

In the spring of 1917 Mr. Stringham had an opportunity to study several fishways in Massachusetts, and to make some observations on the velocities of water up which the fish swam. These fish belonged to the species *Pomolobus pseudoharendus* (Wilson), one of the common alewives. The instrument used to measure the velocity of the water was a Price current meter lent by the Bureau of Standards. Measurements were made of the rate of flow at 7 points in the fishway where the current appeared to be greatest, and it was found to vary from 4 to 5 feet per second. At Middleboro the fish were unable to ascend a little sloping falls where the velocity was about 11 feet per second. Just below they were swimming through one place where the current was 5.3 feet per second. At East Wareham the head of water, and therefore the velocity could be varied. The fish swam up a slope of about 3 feet long where the water was going down at rates of 6.1, 7.8, and even 9.8 feet per second. They were perfectly helpless when it was raised to 13.5 feet per second.

These figures show that for a few feet at least this species can swim through water flowing about 10 feet per second. That is the same figure suggested for the salmon by two different investigators and is the limit suggested for fishways by a third.——Read before the Biologic Society of Washington by EMERSON STRINGHAM; from a report in the *Journal* of the Washington Academy of Sciences.

Rain, Wind and Cyclones

THE author points out that many of the old preconceived notions as to the structure of cyclones have had to be revised in the light of recent knowledge. However, it cannot be doubted that rain is an indication of rising air, since the condensation cannot be brought about by any other means than the cooling due to adiabatic expansion produced by ascent. This inference is borne in mind in looking into the mechanism of certain depressions, and deductions are drawn as to the upper-air movement. In the latter part of the paper the theory of the causation of cyclones is considered.

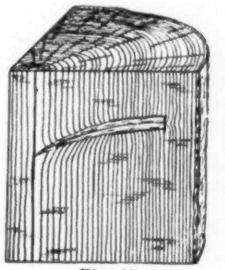
Fig. 12

In the stratosphere the air over a depression is relatively warm up to the greatest height which has been explored with registering balloons, and the data at present available show that the air at great heights over the poles is similarly relatively warm compared with that over the equatorial regions. The present author has previously suggested that this heating of the air over the poles is due to the electrons shot out by the sun, which being caught by the earth's magnetic field, are directed toward the poles, the air in the neighborhood of which they heat and probably ionize. The suggestion is that this heating causes the air to rise with an outflow near the limit of the atmosphere, the supply of air being maintained by the incurvature of the air paths near the surface. Thus the polar depression is accounted for. If we may assume small pencils of cosmic matter which strike the upper layers of the atmosphere in a localized patch, the causation of a travelling depression may be similar to that described above for the polar depression. In this case the travel of the depression would be guided by the motion of the air in the top layers where the heating took effect. This heating is regarded as being produced rapidly and as dying away slowly. It is thought that this theory will account for the observed temperature distribution in a cyclone. It is in contradiction to that advanced by W. H. Dines, who concludes that a cyclone is produced by the withdrawal laterally of the air at a height of from 8 to 10 km.—Note in Sci. Absts. on an article by R. M. DECLEY in *Phil. Mag.*

Timber for Construction

CONTRIBUTIONS recently made to technical literature on the subject of timber as an engineering material have served to direct attention to a subject of more than ordinary interest at the present time. Owing to the difficulty of obtaining supplies of steel it has been necessary to make increasing use of timber for factory construction and other building requirements, while in aeroplane work the need of readily accessible and adequate supplies of certain varieties of timber is particularly urgent. The questions involved have unfortunately received but little attention in this country, and our knowledge of the properties of the material is rudimentary as compared with that of steel and the non-ferrous metals. This is the more to be regretted because there are at least 1,000 different kinds of wood on the commercial market. What is required is in the first place a survey and classification of the timber resources suitable for use in engineering structures, and, secondly, an organized research into the mechanical properties of timber on the lines of that conducted nearly a century ago by Guillaume Wertheim, doubtless the most important investigation of timber as an engineering material that has yet been carried out.—Engineering Supplement of the *London Times*.

The Life of Insects in the Primary Era

A Study of Certain Fossil Remains in France

By August Lameere, Professor of University of Brussels, Member of Royal Academy of Belgium

Through the kindness of Professor Boule I have been enabled to study at the Museum of Paris a marvelous collection of fossil insects of the upper coal strata of Commentry, collected by the skill and knowledge of M. Fayol, and already described in a large part by Charles Brongniart. Specimens collected since the premature death of this excellent naturalist have enabled me to discover new facts, which complete and modify in a certain measure the ideas previously formed upon the insects of the primary epoch. The work of Charles Brongniart, highly meritorious and truly beautiful, was a veritable revelation; it required a gigantic effort; which has perhaps not been sufficiently appreciated. What few wings of insects were then known have been described principally by Goldenberg and by Scudder; the science had been shunted on to the wrong track by the erroneous theory of Adolph on the "Nervation of Wings," and Brongniart did not possess the key discovered later by the American entomologists, Comstock and Needham, which enables us today to comprehend the evolution of nervures, and to follow those which have the same origin in the wings of all insects. A few years ago the Austrian etomologist, Handlirsch, subsidized by the Academy of Vienna, undertook a revision of all the fossil insects, and the results of his investigations have been coordinated in an enormous work, "Die Fossilen Insekten," which has become the bible of the etomology of the past.

Handlirsch went to the United States and to Belgium in order to study the comparatively rare primary insects which have been collected in these two countries; but he neglected to examine the English material, which we are beginning to know through the efforts of Mr. Bolton, the Director of the Bristol Museum; he did not come to Paris to see the fossils of Commentry, which constitute by far the richest source of documents which we possess on primary insects. He accepted the work of Brongniart, which we might consider as homage rendered to the French savant, if Handlirsch had not been led, under the influence of proconceived ideas, to denature Brongniart's work, and had not at times discarded the latter's conclusions, which are, however, based on well-known facts. Instead of examining the precise text of the work and the original drawings, which are very exact as I have been able to assure myself, and which the author tells us were executed by himself, Handlirsch examined the photogravures which accompained the work, and which are comparatively rough because of the still imperfect processes of reproduction at that time; also he has often made use of literal copies of defective figures, drawn not by Brongniart, but by a not very competent artist. Grave mistakes have resulted from this mode of procedure, and Handlirsch arrived at a very inexact view of the fauna of the primary insects. Unfortunately, the prestige of Germanic science or the personality of the author, who is an entomologist of the first order have caused these erroneous conceptions to be accepted in a majority of recent treatises upon zoology and paleontology.

The insects of the primary epoch are of exceptional interest. In the first place, from a point of view merely of the knowledge of insects, these marvelous jewels of nature of which Charles Nodier observed, that those who have not loved them have lacked a sense enabling them thoroughly to enjoy life; again, with respect to our conceptions of evolution the features presented by the fauna of the primary insects comprise more than one piece of information having a general application. Finally, let us not forget that it was the presence of these organisms which formed the occasion of the transformation of the aquatic vertebrata into the terrestrial vertebrata; at the time, probably in the carboniferous epoch when the crossopterygian fishes left the water and became first amphibians, and then reptiles, they could not have done so except upon the condition of being able to find suitable nourishment upon the solid earth, and it was the insects which provided them with this food. It does not seem to me paradoxical to say that man, himself, owes his existence to the primary insects. The insects preceded the vertebrata in fact, and probably by a very long time, in their invasion of the continents. It is true that we do not know any fossil previous to the Lower Carboniferous, for the blattidae of the Silurian, called the *Palaeoblattina Douvillei*, by Brongniart is only a genal point of the trilobite, as was proved by Agnus, and the insects of the New Brunswick, described by Scudder as belonging to the Devonian, are in reality of the Middle Carboniferous. But, contrary to the opinion of Handlirsch we are able to demonstrate that the insects of the Lower Carboniferous are already specialized, and that they belong to three different orders, even those of the Subulicornes, of the Protohemiptera and of the Orthoptera; hence, it must have been before this period that the Hexapods not merely detached themselves from the stock of the Archaic Myriapods, already become terrestrial, and not only passed from the primitive wingless state of the Tbysanoura to that of the winged insect; but they must also have previously undergone their expansion into very distinct orders. It is quite certain that they must have already existed in the Lower Carboniferous or Devonian, since, at that time, perfected Myriapods existed, and that the vasicular plants had had sufficient time to produce Spermatophytes, even so highly evolved as the Cordital. The discovery of the Scorpions of the Silurian would even have as a corollary the presence of insects during this period, if we did not know that the scorpions of the Silurian have been found in marine deposits. No animal and terrestrial plant of the Silurian is known to us; some of them probably existed, and there is nothing to prevent us from thinking that the Hexapods had already been created at that time. As yet we possess only seven species of fossil insects of the Lower Carboniferous, less than one hundred of the Middle Carboniferous corresponding to the Westphalian, several hundred of the Upper Carboniferous or Stephanian, and the number of insects found in the Permian is considerably less. This last fact shows what small value should be attached to these statistical data relative to the estimation of the number of species; what these fossils show quite perfectly, if we examine each group in particular, is that there was an evolution of insects from the Lower Carboniferous to the Permian, for we remain almost entirely ignorant of the genealogy of the orders; but we cannot say that there was at the same time an increase in the number of species, the large quantity of fossils of which we have knowledge in the Upper Carboniferous being essentially due to the fortuitous circumstances of the discovery of the exceptionally rare Commentry deposit; neither can we affirm that during this period insects increased in size. To be sure, we find in the Upper Carboniferous of Commentry the greatest insect known, the celebrated Libellula, ***Manganeura Monyi*** having a spread of seventy centimeters; but this is an isolated fact, and there were very small insects at that time also; a number of others were large, some of them even very large, which must have had a spread of forty centimeters, existed in the Middle Carboniferous, and perhaps in the Lower Carboniferous, just as we know some of our own times almost as large. If the researches made at Commentry have not caused the discovery of many insects of tiny size, this was evidently due to their being so difficult to detect, even supposing that they were fossilized. It is very remarkable, however, to note the presence at Commentry of so many species of considerable size. The fact indicates an extraordinary pullulation of life, the more curious, since Commentry was then in a comparatively small island which formed, it is true, a portion of an archipelago. The plants of the epoch, Pteridophytes, Cycadofilicals, Cordaïtals, fell from the heights of the central plateau into a lake, where the stephanian coal was formed. The presence of this lake affords an explanation of the relatively enormous quantity of fossil types whose larvae must have been aquatic, types lying on the borders of bodies of water, and very rare in other carboniferous deposits. The blattidae are the most enormous, as indeed they are everywhere for, living in the detritus of forests, they were easily carried away by torrents. Fossils of those forms which lived on trees, or which were capable of escape by jumping, are on the contrary, comparatively rare.

* * *

The Thysanours of primary times are unknown to us, the ***Dasyleptus Lucasi***, considered as such by Brongniart, being a crustacean. The winged insects, the Ptilotea, as they were called by Artistotle, form two great categories; the first, when in repose spread their wings in a flat plane, perpendicular to the length of the body, as the large Libellulae do today; the others, like crickets, had already become able to close their wings over the back, and were consequently more evolved. The first group comprises the ancestors of the Ephemera, the Libellulae and the Hemiptera; the second comprises the other insects.

Professor Henneguy, long ago called attention to the fact that, from the embryological point of view, the winged insects can be classified in two divisions, of which one, the more primitive, is formed of the Ephemera, Libellula and the Hemiptera. These insects, in fact, are endoblastic, that is, their embryo is recurved, and reenters the vitellarium precisely as in the case of the Thysanoura, a phenomenon which recalls a peculiarity exhibited by the embryos of the Myriapods; the other winged insects, on the contrary, are ectoblastic, their embryo remaining at the surface of the egg. This association of the cirades and the bugs with the Ephemera and the Libellula may seem paradoxical, but it is fully confirmed by paleontology; we might even transport into the systematic realm, M. Henneguy expressions and divide the Ptilotea into the endoblastic and the ectoblastic.

The resemblance between the fossil forms, from which descend the Ephemera and the Libellula on the one hand, and the brotohemiptera, ancestors of the Hemiptera on the other hand, is so great, in fact, that Handlirsch has failed to perceive the difference between them: He has confounded all these insects in a single order, which he considers to have given birth to all the others, the Paleodictyoptera. These Endoblasts of the primary not only have a very analogus nervation identical subuleated antennae, primitive legs, *cirques*, these abdominal antennae having the structure of long articulated filaments; but when the body has been preserved it shows some very curious peculiarities. This body is wide and flat, with equal rings; the prothorax exhibits highly developed ailerons which have ceased to exist, or of which mere traces exist, in the ectoblatts, even when these belong to the carboniferous. Finally each of these ten dorsal arches of the abdomen presents lateral apophyses in the form of plates called *ailettes*, which Brongniart was wrong, as I believe I have proved, in taking to be trachean gills.

These abdominal ailettes, the prothoracic ailerons, the Mesothoracic or metathoracic wings have an equivalent morphological value. It is these which are called the ephemera in the crustacean; the pleuras in the trilobites; we find these forms among the *Machilis*, the most primitive of the Thysonoura, where they are considerably more developed at the thorax than at the abdomen; other sizes being proportional to that of the segments, which bear them.

When the jumping Thysonoura, like the *Machilis*, becomes transformed into the Ptilota according to the highly probable hypothesis of Grassi (for the old conception of Oken that the wings are a modification of trachean branches is definitely abandoned), the three pairs of thoracic ailerons commence to act as a parachute; but those of the mesothorax, and of the metathorax, which are nearer the center of gravity, do not become movable, and do not develop into true wings, dispersion organs of the adult. In the Endoblasts of the primary epoch, we find on the prothorax ailerons in the state in which the mesothoracic and metathoracic wings themselves were primitively found. These prothoracic ailerons probably continued to play their role of parachute among insects which were rather heavy, but capable of sustained flight; for all things considered, they do not appear to me to have been movable; hence, insects have never possessed six "wings."

* * *

One of the facts which stands out most clearly from the study I have made of the insects of Commentry is the demonstration of the unity of origin of the Ephemera and the Libellula. This result was to be expected, for these insects have a very similar nervation, and their larvae, adapted to life in fresh water, are not fundamentally different; hence, I have been able to reconstitute the order of the Subulicornes of Latreille, which had been abandoned by reason of their erroneous joining to the group of the Perla; the latter are likewise aquatic larvae, but entirely different from those of the subulicornes, and the adults have the general characteristics of the orthoptera.

The Subulicornes comprise therefore the Ephemeroptera and the Odonatopters, whose buccal appendices have retained the primitive structure of browsing organs, while the Rhynchotes, Protohemiptera and Hemiptera are sucking endoblaststs. The common ancestors of the Ephemera and the Libellula belong to the Ephemeropter, which compose the category of the Spilateroids, themselves composed of two families, the Spilapteridae and the Megasecopteridae; these insects must have had aquatic larvae since this is the case in the two groups which descend from them. Their presence in great numbers at Commentry supports this view.

Moreover, only a few very rare representatives of these are found in the Middle Carboniferous and one form of the Permian. The Spilopteridae were insects of comparatively large size; they resemble butterflies by reason of their light colored spots, often arranged in transverse bands, clearly marked upon the dark background of the wings; but their flight, though sustained, must still have been heavy.

Connected with the Spilopteridae are the Megasecopteridae, which are much more perfected; the superior forms of the family were large insects which must have flown with great ease; their wings, usually ornamented with eye-like spots, had the form of those of swallows; they were very light, the nervation being reduced to a minimum; but these nervures were curiously buttressed one above the other, so as to give at the same time the maximum of solidity to the organ. The forelegs were shortened and fitted for grasping like those of the Nepa, the insect being able to cross them under its mouth in order to hold the prey which it seized when flying. The admirable Sublicornes are not found later than the Permean, and they represent a very superior branch which has become completely extinct. The only Ephemeroptera which have survived until our own time, and which have even undergone constant evolution since the carbonferous, are the Ephemeroids. They do not descend from the Megasecopteridae, but probably from small Spilapteridae. The Commentry collection contains a fossil which is as corrobatory in this respect as is the *Archeopteryx* for the origin of the birds. It is a Spilapterida which already exhibits the original peculiarities of the Ephemera, or if one prefers, it is an Ephemera, but an absolutely primitive Ephemera which does not lift its wings vertically in repose, and which still has the lower wings as large as the upper wings.

Thus, the Ephemeroptera of the Primary offer to our consideration three types which have been perfected in two different directions; the large and splendid Megasecopteridae on one hand, which died leaving secondary descendants, and the small Ephemeroids on the other, which only begin to show themselves timidly in the Upper Carboriferous, and which have been undergoing evolution down to the present time.

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The Odonatoptera exhibit an exactly parallel table of evolution.

In the Middle Carboniferous, and in the Upper Carboniferous there are found numerous Subulicornes, which are connected with the Spilapteridae. They differ from them only by their wings, which like those of the Libellula are as resistant as taffeta silk, and by their transverse nervures, which in place of the simple bars, which give such a slight consistency to the wing of the Ephemera, inosculate to form a network. These insects are the Srenodictyoids, which, in spite of having bodies still wide and thick, must have been able to fly more rapidly than the Spilapteridae, since their wings were generally long and narrow.

None is known in the Permian; but in the Middle Carboniferous they had already given birth to the Odonatoids of the group of the Protodonata. These Protodonata, which are to the Stenodictyoids what the Megasecopteridae are to the Spilapteridae; had, like the Libellula of the present day, wings improved by the turning up of the base, causing the principal nervures to touch each other, thus securing greater firmness. The genus *Meganeura* is the principal representative of these: four species of those gradually increasing in size are found at Commentry, the smallest, being itself almost gigantic, while the largest seems to have been the most formidable insect that ever existed. These carnivorous monsters died without leaving any descendants, for it was not from them that the present Libellula, the Odonata has proceeded. The true Odonata, whose wing presents a new improvement, securing for it a still greater rigidity, can be connected only with the Protondonata of medium size, less highly evolved than the *Meganeura*, and its contemporaries. The oldest Odonata which I have thus far been able to find was, moreover, a small fossil of the Rhetian, the lowest stage of the Lias. The only Odonatoid known in the Permean is still a Protodonata, which is not larger than the largest Libellula of the present time.

As among the Ephemeroptera, we find three types among the Odonateoptera: the precursory type, the Stenodictyoids which became extinct with the carboniferous; an improved type, the Protodonata, likewise extinct, but only in the Permean; and another type still more improved, which has been in constant evolution down to our own day, the Odanara, the latter descending from the most perfect forms of the Protodonata.

Thus we find confirmed both by the Ephemeroptera and by the Odonoptera the fact already proved by other groups of organisms, that it is not the most highly evolved forms of an epoch which give rise to the most highly evolved forms of the subsequent epoch: aristocracies do not last, and the giants die without leaving descendants.

* * *

What is the reason for the disappearance of all these beautiful insects having aquatic larvae? How does it happen that only the frail Ephemera, and the little Libellula have survived?

The cause of this phenomenon, it seems to me, must be parallel with those which brought about the extinction of all the large plants of the primary epoch. The majestic trees which were produced by the vascular Cryptograms, Lycopodials, and Equisetals, as well as by the Spermatophytes, the Cycadofilicals and Cordaitals. In the secondary, these primitive plants are placed by shrubs, conifers and bennetitals, from which the angiosperms were to proceed. It is probable that the fault is to be found in the change of the conditions of the climate; the carboniferous period must have been very humid. The atmospheric precipitations favoring the production of wide rivers and great lakes. A drying out must have occurred at the beginning of the Permean epoch: and thus it was fatal to the perfected forms which were closely adapted to the surrounding conditions; only the less exacting types escaped destruction. The larvae of the Subulicorneas of large size had need of large expanses of water in order to find their subsistence and when these immense swamps ceased to exist they perished; their fate was like that of the Crocopterygians, the Dipneusts, the Pleuracanthians. The forms of small size, the Ephemera and Libellula, which were able to content themselves with smaller rivulets and moderate ponds were spared, all the more since, by a sort of preadaptation, they possessed characteristics superior to those of their imposing contemporaries.

* * *

The Rhynchotes of primary times afford us another example of the exinction of a gigantic type, well adapted to the special conditions of the epoch and of its replacement by modest descendants, which were more in harmony with a new environment.

A singular fossil insect of the lower Permean of Germany, the celebrated *Eugereon Boeckingi* has long been known. It is a figure of large size with wings spread out flat, prependicularly to the length of the body, which presents a very long beak shaped in a general way like that of the Hemiptera of the present time. This "Libellula with the bug's Trumpet," as this insect is called in certain elementary works, constituted up to the present time the sole member of the group of the Protohemiptera, distinct from other Rhynchotes or Hemipoptera, which have wings arranged on the back of the abdomen when at rest.

Charles Brongniart recognized perfectly in one Commentry insect a Protohemiptera, but Handlirsch did not have confidence in the representation of it which had been given, and considered it to be an incomprehensible fossil. The French savant also put to one side among his Neuroptera, a whole group of genera of the carboniferous, the Dictyopteridae, which Handlirsch had grouped with the Ephemeroptera and the Odonatoptera of the primary in his order of Paleodictyoptera.

In studying the Commentry material I verified the fact, not only that Brongniart was right in noting the presence of the Protohemiptera in the carboniferous but that one of the fossils which he had placed among his Dictyopteridae exhibited in two specimens a magnificent rostrum, arranged vertically and very well preserved. I then found that the Dictyopteridae exhibited, like the Protohemiptera of Brongniart, a characteristic nervation which is that of the *Eugereon*, and which enables us to make an exact separation of these insects from the Subulicornes: It results from this that there was at the epoch of the Upper Carboniferous a collection very well provided with Protohemiptera, all of large or of rather large dimensions, one of them even having nearly forty centimeters spread. Moreover, by taking the nervation as a basis, it is possible to recognize the existence of the Protohemptera in the Middle Carboniferous, in which they have already become quite numerous and of considerable size; and even in the Lower Carboniferous also. The *Lithomantis Carbonaria* shown in so many works belongs here, as does the famous *Breyeria Borinensis*, the Belgian fossil which has given rise to so many discussions. The *Eugereon Boeckingi*, therefore, is the terminal form of a long line.

Did the Protohemiptera of the Lower Carboniferous already possess buccal appendices, arranged for sucking, or were they still browsers? We are still ignorant as to this, all we may venture to say is that the arrangement of the nervures in their wings may be related to that of the most archaic Subulicornes. The Subulicornes of the Lower and Middle Carboniferous, which form a small distinct group of the Spilopteridae, was still more primitive and perhaps did not yet have larvae adapted to life in fresh waters.

We cannot, in fact, accept Handlirsch's view that all insects had an aquatic origin; for in that case, we should not be able to comprehend how they could possess tracheas; the larvae of the first Subulicornes were apparently terrestrial like the Thysanoura, and it was from these Subulicornes that the Rhynchotes were probably descended.

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The Protohemiptera must have lived in the same manner in all their states of existence as do the Hemiptera at the present time, and their structure shows that they were not aquatic. These are the heavy insects with wings of homogeneous texture, but rather firm, adorned with spots like those of the Spilopteridae; their strong robust legs are elongated in form, so as to enable them to hook on to plants. We consider them to have been phytophagous, and the length of their rostrum in contrast to the shortness of that of the Hemiptera is possibly to be explained in the following manner: the Protohemiptera, which would not have had a very long and vertical rostrum if they had attacked leaves and *á fortiori* if they had been carnivorous, must have sunk this proboscis into the well developed trunks of the trees of the Primary Era; but these trunks were of different constitution from those of the Conifers and of the Dicotyledons of the present time: the nourishing *Liber* was placed deep beneath a very thick bark and not near the surface. The Protohemiptera were probably the gigantic Cochineals and lice of the Lycopodials, the Equisetals, Cycadofilicals and the Cordaitals of the carbonferous. They accompained these trees as far as the Permean and disappeared with them for lack of nourishment, incapable of adapting themselves to the shrubs of the secondary era, conifers and bennettitals.

At the Epoch of the Upper Carboniferous they had already given birth to the true Hemiptera which were destined to perpetuate themselves in a flourishing state down to our own time. The Protohemiptera distinguished by Brongniart is smaller than all the others, and it clearly shows a tendency to become a Hemiptera; Brongniart described moreover a Commentry fossil, which he regarded as the true Hemiptera, and rightly so, though Handlirsch had considered it also as being enigmatic. The small wing of this insect, in fact, shows by its nervation that in repose it was spread over the back of the abdomen. In the Permean, moreover, two representatives of the order of the Hemiptera are known, one of which is the primitive Homoptera, with wings of uniform texture like those of the Protohemiptera, while the other has already become a Heteroptera, exhibiting a nervation still very similar to that of the Homoptera, but with the upper wings transformed into Hemelytra.

It was thus that the ancestors of the Protohemiptera perished at the end of the primary, too well adapted to the superannuated regime; they were replaced by the descendents of those among them which had less exclusive requirements, which contented themselves, therefore, with small roles, and which formed a democracy whose very modesty was to constitute its superiority for the future.

The drought caused the disappearance of the mighty ones among the Subulicorne; the same thing is true for the Pteridophytes and the Gymnosperus, and the extinction of the primitive trees brought about that of the Protohemiptera, which were their parasites.

Gigantism, which exhibits a perfect adaptation to definite conditions of existence, is not in itself a cause of the disappearance of organisms. The gigantic insects lived during the carboniferous period; their annihilation was the result of external causes which suppressed the environment upon which their life was dependent.

* * *

The evolution of the Ectoblasts shows very different features, more archaic than those which we have shown to be true of the Endoblasts. These insects which had already begun to cover the back of the abdomen with their wings at the beginning of the carboniferous, present themselves at the present time as being divided into two categories. There are those which are said to have incomplete Paurometabolic metamorphoses, and those which exhibit a true metamorphosis, the Holometabolics.

The Paurometabolics are the Orthoptera, taking this expression in its widest sense. The different groups which constitute them are nearly all already presented, and even separated from each other in the carboniferous epoch, so that it is very difficult to preceive their genealogical relations. Contrary to the opinion of Handlirsch, and conformably to that of Brongniart, I believe, in fact, that these primary fossils can all be related to categories existing at the present time, and that we are concerned with the direct ancestors of the latter. There have not been, as in the case of the Endoblasts,

great hecatombs of highly specialized types, and this is probably because these insects were adapted to conditions which have been perpetuated down to the present time.

Among materials which were not examined by Brongniart I have found a fossil which is the smallest insect of Commentry. It has a spread of only 20 millimeters, and it appears to me to belong to the group of the Psocides, those lice of the woods which feed on lichens, and which were the ancestors of the true lice. Psocides have been recognized as early as the Permean of the Lias. Brongniart described a *Protoferla* genus, which he regarded as a precursor to the present Perlidae, and I am of his opinion in spite of Handlirsch. There also are small insects which must be related to the primitive Paurometabolic, like Psocides, since their wings are still membraneous.

We now arrive at the imposing legion of the *Blattidae*, in which the most primitive types are small insects, very similar to the ancestors of the *Perla*. It is interesting to note the simultaneous presence at Commentry of very archaic forms of the group, together with highly perfected blattidae in a whole collection of insects having very different genealogical values. We find here, besides the generalized precursors, specialized precursors which have not left descendants; there are also blattidae which are well characterized, but which still retain the original terebra of the insects which all other blattidae have lost; then there are blattidae constituting categories which are very original, and are now extinct; and there are also others which clearly indicate those of subsequent epochs. None of them, however, has the complete characteristics of the blattidae of today, and none of them shows the tendency to pass into the type of the Termites, which was not detached from the group until the tertiary. It is an extraordinary confusion of ancestral forms, and contemporaneous derived forms, bearing witness to the prodigious exuberance of life on the soil of the forests heaped with vegetable debris. The insects devouring such detritus obviously hid themselves among it as modern blattidae still do, and it is curious to note that the nervation of the wings of the whole group, which has now disappeared, sometimes resembles that of the leaves of certain Cycadofilicals to such an extent as to make it easy to mistake one for the other. This was evidently a pure coincidence and not a protective resemblance produced by natural selection.

The principal carnivorous Ecotoblasts of the epoch form a group which seems close to the *Blattidae*, and already well represented in the Middle Carboniferous. One of the Commentry genera had been regarded by Brongniart as constituting a special category of Orthoptera, the Hadrobrachypods which he believed to have affinities with the Mantis; Handlirsch had placed some in the order of the Protohemiptera; others among the Protoblattoids. These are great running Hexapods with long frail legs which must have been very agile; their general aspect is that of the Mantis; there are even some which have like the latter grasping forelegs, or great spots resembling eyes upon the wings. But there are differential characters, and these characters, which are foreign to the Mantis, are found among the Holometabolics of the order of the Megaloptera, so that the relationship with the latter might be implied. On the whole, however, I believe this approximation to be factitious, and I think, in fine, that it concerns primitive Manotoids.

* * *

Confirming the contrast with other Paurometabolics by their head inserted in the prothorax, and by their robust legs formed no longer for running, but for walking or jumping. The Phasmoids and the Locustoids of our modern fauna, which are markedly phytophagous, still exhibit in their wings peculiarties which lead us to consider them as having probably had a common ancestry. The wings of the Lower Carboniferous and of the Middle Carboniferous seem to presage the advent of this group of Orthoptera; but it is difficult to pronounce a definite opinion as to this with these documents alone.

The Phasmoids are represented at Commentry by several genera, the most important of which is the celebrated *Protophasma Dumasi*, the first primary fossil insect to be found in France, and the largest among the Ectoblasts of the epoch. It was the opinion of Brongniart that it was necessary to regard this Orthoptera as a precursor of our Bacillus, and of our Phyllium, those animated sticks and leaves. Handlirsch objected vigorously to this view, and considered the Protophasma to be a Problattoid, disdaining the drawing made by Brongniart.

The Austrian savant holds that there could not have been any Phasmoids in the Primary Era, for, according to him, no vegetarian insects could have existed at that period, since at the present time ferns are almost never attacked by insects. The process is strange, to say the least, and the reasoning singular, especially if we remember that the *Filicials* were not by any means the dominant plants in the Primary Era.

I am in entire concordance with Brongniart's view; the *Protophasma* and its companions have all the essential characters of the Phasmoids, and if they differ in certain points from present day Phasmids, just as the Hadrobrachy pods are not identical with the Mantids, these differences are not such as to render us unable to regard these Orthopteridae as forming part of the same line. These large insects, with a narrow elongated body, with strong legs made for walking slowly, must have had the behavior of the Phasmae and also their regimen; they apparently walked on trees, and browsed upon the young shoots, and perhaps even devoured the seeds.

At Commentry, finally, some fossils have been found whose elongated posterior legs and swollen femur were adapted for jumping. These insects show, moreover, the general conformation of the Locustoids, and they even present themselves under two aspects: the nervation of the wings of the one kind recalls that of the Locustids, while that of the others has exhibited the distinctive mark of the Acridiides. However, there seems to have been as yet no apparatus for stridulation, but there is nothing to prevent us from seeing in these Orthopterides, as does Brongniart, the precursors of our own grasshoppers and crickets.

The fauna of the Paurometabolics of the Upper Carboniferous presents therefore almost completely the same features as does that of today, and save for the Termites, the Earwigs, and the Thrips, all the modern groups are already represented there.

* * *

The beginning of the Secondary Era produced something new under the sun; the startling multiplication of insects which undergo complete metamorphoses. We have as yet no really positive proof of the presence of Holometabolics in the primary, although there are some indications of their existence at that time. The most ancient of these fossils which we possess belong to the Trias: they belong to the order of the Cleopterae and to the order which it is today the custom to call the Nevtopterae, but, in order to avoid all confusion, I think it would be better to apply to this category the denomination Megalopterae, used by Latreille. All the Holometabolics of the Trias, which are, besides, very few in number, are of small size, and it may be by reason of this fact that their primary precursors have thus far escaped us.

According to their characters these Ectoblasts can be related only to the Paurometabolics, but they seem not to be descended from any type of Paurometabolics represented in nature at the present time. We can only believe that their stock must be found among the most primitive Paurometabolics, among those which still possessed membraneous wings, and consequently it is necessary to go back at least as far as the Upper Carboniferous in order to discover their ancestors.

Handlirsch, who supposes four different origins for the Holometabolics, has attributed the appearance of complete metamorphoses to the Permean glacial period, which would have involved the nymphal repose; but this explanation does not take into account the highly original characters of the larvae of the Holometabolics, and it seems scarcely convincing, for the nymph stage never coincides at the present time with winter periods.

I long ago gave utterance to the hypothesis that the Holometabolics form, on the contrary, a monogenetic group, and that their origin bears a definite relation to the penetration of insects into the interior of plant tissues and probably into the trunks of trees.

I am the first to recognize that we are here concerned only with a hypothesis. Admitting that the point of view is not erroneous, the small success of the Holometabolics in primary times may perhaps be explained by the nature of the plant life of that period: the trunks, which were exploitable for the Photohemipteridae were scarcely so for perforating larvae, the bark being too thick and the liber too deeply placed. Only the conifers and the ginkos which begin to present themselves at the end of the Primary, could, by means of their continuous and superficial liber have assured the existence of larvae obliged to breathe. When once constituted, the Holometabolics might adapt themselves little by little, by reason of the excellence of their post embryonic development, to every imaginable kind of life, which was the work of the Secondary Era.

* * *

It is thus that we may represent to ourselves the appearance of the entomological fauna of primary times in its essential features, and by making use of hypothesis.

In the fresh waters lived the larvae of numerous Subulicornes; they were able to nourish themselves on an abundant plankton, and the larger ones devoured the smaller. The Fish, the Amphibians, and the Crustaceans, some of which were enormous, as the *Arthropleusa*, helped to diminish the number.

Along the borders of the lakes flew, like heavy Butterflies, Ephemeropteridae of the family of the Spilapteridae, which perhaps ceased to take food in coming to the adult state, like the Ephemeras of the present day. The large slim Megasecopteridae captured them on the wing, as also the various Odonatopteridae must have done, and particularly the gigantic Protodonata. The latter probably respected nothing, and the large Protohemipteridae were doubtless frequently their victims when first they tried their wings.

In the forests these pullulated among the detritus upon the ground blattidae (cockroach-like insects) of every kind; to their enemies, principally Arachnids, were added agile Nlantoids which chased them on foot.

Upon the trees great Protohemipteridae sunk their long beaks into the stems to suck the sap; beautifully shaped Phasmoids promenaded slowly along the branches gnawing the foilage. There too doubtless lived the jumping Locustoids.

It was like a tropical fauna of today, but minus the buzzing of the flies, the bees, or the coleopteridae, without the chirping of the locusts, the grasshoppers, and the crickets, in a nature without either birds or mammals, biologically silent.

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